IMPACT OF INCREASING STREAMFLOW IN THE RIO GRANDE RIVER

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Rocky Mountain Forest and Range Experiment Station

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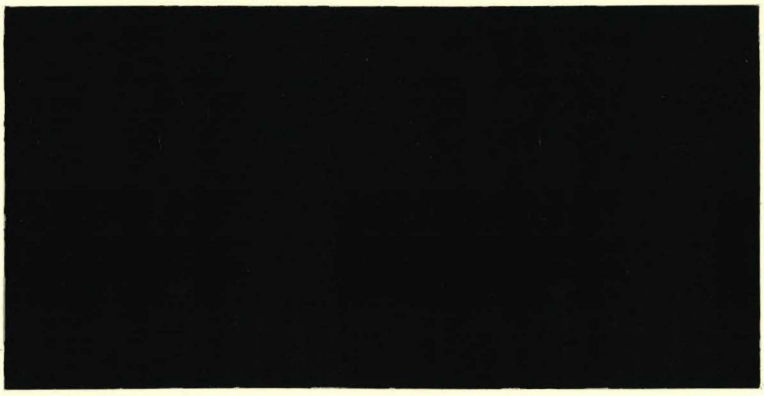

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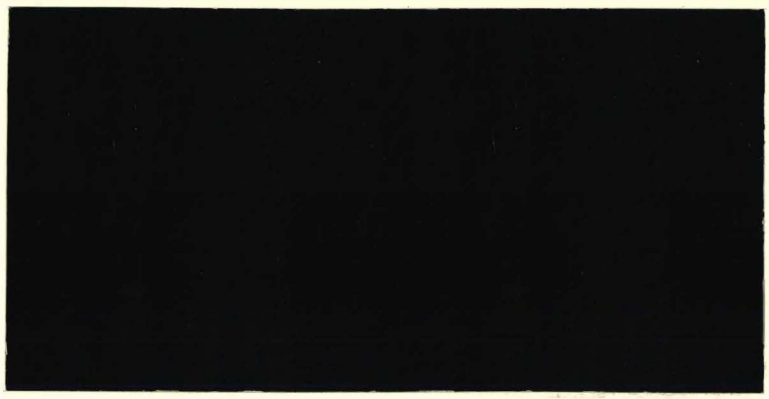

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The following study has been completed under research contract No. 28-K3-297 between the USDA Forest Service and Steffen Robertson and Kirsten (Colorado) Inc. The following report is the result of the combined efforts of the USDA Forest Service Contracting Officer Technical Representatives (Mr. Tom Brown and Mr. Don Rosenthal), the Civil Engineering Department at Colorado State University (Dr. John Labadie and Mr. Phil Graham), Mr. Craig Green (Terra Therma), Mr. George Radosovich (Radosovich and Associates), and Steffen Robertson and Kirsten.

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1.0 INTRODUCTION

1.1 Statement of The Problem

The U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station has initiated several studies to assist public land management agencies in comparing the benefits and costs of streamflow augmentation practices. The objective of the studies is to determine whether implementation of such practices is warranted, and to address the effects on downstream uses and potential re-use of additional streamflows. Distribution and use of such streamflow increases are affected by the following factors;

- The legal and institutional framework governing water allocation;
- Existing and potential future water distribution networks;
- Historical, existing and future use patterns; and
- Hydrologic regimes.

The study results presented in this report are for the Rio Grande River basin. With its headwaters in south central Colorado, the Rio Grande River travels through central New Mexico, forms the border between Texas and the Republic of Mexico, and ultimately drains to the Gulf of Mexico. This study deals with augmented streamflows from silvicultural activities on property under the jurisdiction of the Forest Service in Colorado, i.e. the Rio Grande National Forest in the headwaters of the Rio Grande River.

1.2 Terms of Reference

The terms of reference for this study are outlined in the "Proposal for Identification of Uses of Increased Streamflow Leaving the Rio Grande National Forest in the Rio Grande River" which was submitted to the Forest Service in response to

Solicitation No. RFP-28-K3-297 by Steffen Robertson and Kirsten (SRK) in September, 1983. Authorization for these studies was received on September 27, 1983.

1.3 Scope of Work

A four-task work program was completed as part of this study. A summary of these tasks, including a description of generalized task objectives, is given below.

Task 1 - Preliminary Literature Search - Review

The objective of this task was to define the components of the river basin system including the existing legal/institutional framework, existing water distribution systems, and institutional concerns which impact the development of water resources in the basin.

Task 2 - Development of a Detailed Study Plan

This task was aimed at developing a detailed study plan based on the Task 1 findings and the overall objectives of the Forest Service.

Task 3 - Technical Evaluation

The objective of this task was to perform all necessary technical evaluations to predict the impact of additional quantities of water on downstream water use (including existing and potential water users).

Task 4 - Reporting

This task included the documentation of the study results and the development of study conclusions.

Baseline hydrologic data relating to augmented streamflows and preliminary information on the value of surface irrigation water in the San Luis Valley were provided by the Forest Service. Summaries of this information along with additional information developed by SRK are included in this report.

1.4 Study Approach

In order to complete the tasks described above and to achieve the study objectives, a computer model was set up and used to determine the distribution of the marginal increases in water supply under various scenarios. The model simulates on a weekly or monthly basis the allocation of water within the basin subject to the legal/institutional framework, the input hydrology and the pertinent state appropriation policies determined by water rights. The benefits of the proposed silvicultural activities are derived from the model output which provides information on how the additional water would be distributed. Where possible, approximate dollar amounts are ascribed to these benefits.

2.0 STUDY DATA

In order to complete the assessment of the economic value of augmented streamflows, data on the physical aspects of the system, the legal and institutional framework, hydrology, and the value of water for agricultural, municipal, or industrial use was developed. The following sections summarize these data.

2.1 Description of the System

The Rio Grande River has its headwaters in the San Juan Mountains of Colorado and then flows into the broad smooth plain of the San Luis Valley (Figure 3.1). The valley ranges in elevation from 7,440 to 8,000 ft and is surrounded by mountains except to the south where the river crosses the Colorado-New Mexico state line. The northern portion of the valley does not drain into the river and is known as the Closed Basin. The Conejos River, a major tributary in Colorado, joins the Rio Grande upstream from the New Mexico border.

In northern New Mexico, the river winds through a canyon for some 70 miles, which has been designated as wild and scenic, before reaching what is referred to as the "Middle Valley". This valley comprises a section of the river made up of a succession of narrow subvalleys separated by short and narrow rock-faced canyons. The Middle Valley is about 200 miles in length and ranges from 4,450 to 5,590 ft in elevation. The subvalleys of Santo Domingo, Albuquerque, Belen, and the northern two-thirds of Socorro constitute the area under the jurisdiction of the Middle Rio Grande Conservancy District.

Continuing south, the river flows through more canyon territory into Elephant Butte Reservoir. This point marks the beginning of the "Elephant Butte-Fort Quitman" section which extends across the state line into Texas. This area of alternating wide plains and subvalleys similar to the Middle Valley includes about 130 miles from Elephant Butte to El Paso and another 80 miles

beyond El Paso to Fort Quitman. The elevation ranges from 3,400 to 4,200 ft. The Rio Grande Project includes the Rincon and Mesilla Valleys in New Mexico and the northern half of the El Paso Valley in Texas.

From the New Mexico state line, the Rio Grande meanders in a southeasterly direction serving as the international border between the State of Texas and Mexico, eventually discharging into the Gulf of Mexico. The river basin is divided into two distinct sections at Fort Quitman. The northern part is generally referred to as the upper Rio Grande Basin. The portion between Fort Quitman and the Gulf of Mexico is generally known as the Lower Rio Grande Basin.

Agricultural activity in the Rio Grande River basin was started at an unknown date by Pueblo Indians or their predecessors. Due to the arid climate, irrigation was practiced. Spanish colonization of the Middle and Elephant Butte-Fort Quitman sections expanded the use of irrigation during the seventeenth and eighteenth centuries. Irrigation by settlers was initiated in the San Luis Valley in the early 1850's and became extensive around 1880. Water rights were established during this time, the oldest of which are on the Conejos River and comprise the most senior water rights in Colorado. In the decade from 1880 to 1890, most of the large canal systems that make up the existing surface water distribution network were constructed.

The irrigation works in the San Luis Valley in Colorado are quite extensive and at one time served to provide agricultural water to the entire central portion of the valley. However, increasing groundwater levels have acted to waterlog portions of the Closed Basin. This resulted in the abandonment of extensive acreage that had once been prosperous agricultural area. As lands in the east and central parts of the valley were taken out of production, agricultural activity moved westward toward the area's mountainous borders. Although there has been some effort at reclamation of these lands, agriculture in the valley today is still centered in the western regions.

In these regions, there are extensive canal and ditch systems to distribute Rio Grande water to its users. Some of the larger canals lie north of the river between Del Norte and Alamosa and provide water to the more prosperous areas of the valley. The largest of these structures is the Rio Grande Canal. Others include Farmers Union Canal, San Luis Valley Canal, and to the south, Monte Vista Canal and Empire Canal. The large canals feed into the many laterals that criss-cross the valley. There is also a multitude of smaller ditches and canals originating from both the Rio Grande and Conejos Rivers. All of these supply entities operate strictly on a priority system of allocation as outlined in Section 2.2.2.

Data available from the State Division Engineer for Water Division No. 3 indicate that an approximate return flow of 12 to 15 percent occurs to the Rio Grande River from surface irrigation in a small portion of the lower basin area referred to as Regions 3 and 4 in Figure 3.1. The State Engineer for Water Division No. 3 also indicates that no return flows occur to the Conejos River as a result of agricultural irrigation (Steve Vandiver, personal communication).

return flows

There are three main reservoirs upstream of Del Norte on Rio Grande tributaries. These are Rio Grande Reservoir, Santa Maria Reservoir, and Continental Reservoir. The total storage capacity for the three is about 120,000 ac-ft. The Rio Grande Reservoir is owned and operated by the San Luis Valley Irrigation District and the other two belong to the Santa Maria Reservoir Company.

Platoro Reservoir is located on the upper Conejos and is the most recently completed storage facility in the region. This reservoir has a capacity of about 67,000 ac-ft and is operated by the U.S. Bureau of Reclamation. It presently does not do much to augment irrigation supply; since the administration of the 1968 stipulation began, Platoro Reservoir with the exception of one year, has been used exclusively for meeting Compact requirements.

? this must free water for irrigation

Irrigation in New Mexico and Texas is on a considerably smaller scale than in Colorado. The Middle Rio Grande Conservancy District and the Rio Grande Project comprise the majority of irrigated agriculture between the Colorado-New Mexico state line and Fort Quitman. The physical methods for distributing surface supply to these areas are similar to those in Colorado, however irrigation occurs primarily in the areas directly adjacent to the river. Instead of distribution via many individual canal and ditch companies, the water supply to these areas is centrally managed by the Conservancy District and the Project. In this regard, the water supply to these areas is not allocated in a strict water-right priority system as is it in Colorado. Instead, water is distributed equitably to water rights shareholders in the districts. Because of the nature of the irrigation valleys in New Mexico and Texas, return flows probably occur. However, as specific data on return flows was not available, estimates of return flow were not included in this study.

Storage facilities in New Mexico include Elephant Butte Reservoir and the Caballo Reservoir just downstream from it. These reservoirs are operated jointly to insure that the supply outlined in the treaty with Mexico is met and to distribute Rio Grande Project water in a timely fashion. The Cochiti Reservoir upstream of Elephant Butte serves as a protective structure for flood control and does not store any agricultural water.

2.2 Legal and Institutional Framework

The arid nature of the Rio Grande Basin suggests that water shortages are prevalent for purely physical reasons. Allocation of water during these shortages, as well as the allocation of occasional surpluses, is primarily a function of the institutional framework of laws, regulations, compacts and agreements which have been formulated by various entities along virtually the entire length of the river. This section discusses the various legal and administrative requirements, as they relate to the present and potential future water allocation within the basin.

The three primary administrative policies that exist on the river today include the (i) international treaty with Mexico, (ii) an interstate agreement, the Rio Grande Compact, and finally (iii) the various state water laws that are used to allocate water within the states.

The international agreement with Mexico requires a constant annual delivery of 60,000 ac-ft which is satisfied through the release of water from Elephant Butte and Caballo Reservoirs in southern New Mexico. This commitment has to be met whether or not a marginal increase of water to the basin occurs. Therefore, it is assumed for the purposes of this report that the international treaty with Mexico is not an important consideration in future as far as the allocation of any increases in streamflow is concerned. The remainder of this section will discuss the other two primary institutional factors: the Rio Grande Compact, and the water law and administrative practices within each state.

2.2.1 Rio Grande Compact

The Rio Grande Compact was signed by representatives of the States of Colorado, New Mexico and Texas on March 18, 1938. A resolution adopted by the Rio Grande Compact Commission changing gaging stations and measurements of deliveries was adopted in February, 1948. Copies of the Compact and the 1948 resolution are included in Appendix A.

In order to insure proper delivery under the Compact, two sets of delivery tables were developed for Colorado, and a single table was devised for the State of New Mexico (see Tables 2.1 and 2.2). These delivery tables specify the amounts to be delivered on an annual basis. They were determined from inflow-outflow relationships developed at the time of Compact

negotiations and were based upon information obtained during the 1928-1937 period. Data on streamflow, diversions and existing water use were compiled at that time by the Rio Grande Joint Investigation Commission and were used as the basis of these inflow-outflow tables. The tables were intended to quantify the existing depletions by existing water users, and their application was supposed to protect the existing water users, including those diverting in the downstream portions of the basin.

Although the Compact was not strictly administered until 1968, it is very much in effect today, and essentially provides a downstream delivery obligation from each of the upstream states to the lower state(s). Due to large debits that were accrued by the mid-1960's, a stipulation was entered into by the three states in 1968, in which the State of Colorado agreed to deliver each year's Compact commitment without building up any further debt of water. This agreement was precipitated by a lawsuit filed by both Texas and New Mexico in 1966, in which Colorado's debt of almost one million ac-ft (built up over a 17-yr period) was the central issue. A copy of the stipulation is presented at the back of Appendix A.

Since 1968, the Colorado State Engineer has had the duty to curtail Colorado water use as necessary in order to meet the delivery requirements for each particular year. The Compact was intended to allocate <u>surplus</u> water, and was not supposed to affect existing (pre-1937) water rights. However, since 1968 there has been a severe curtailment of pre-Compact water rights in order to meet the Compact. One of the reasons for this is the extensive water-well development that occurred in the San Luis Valley during the 1950's and 1960's. These

TABLE 2.1

COLORADO DELIVERY OBLIGATIONS ACCORDING TO THE INTERSTATE COMPACT[2]

Conejos River			Rio Grande River (Exclusive of Conejos)		
Flow at Conejos index flow Station[1] (ac-ftx1000)	Delivery required on the Conejos at mouth[1] (ac-ftx1000)	(% index flow)	Flow at Del Norte Station (ac-ftx1000)	Delivery required at Lobatos less Conejos requirement at mouth[1] (ac-ftx1000)	(% Del Norte flow)
100	0	(0%)	200	60	(30%)
200	45	(22%)	400	98	(25%)
400	188	(47%)	600	161	(27%)
600	376	(63%)	800	257	(32%)
700	476	(68%)	1000	430	(43%)
			1200	640	(53%)
			1400	840	(60%)

Note 1. See Figure 3.1 for gaging station location.

TABLE 2.2

NEW MEXICO DELIVER OBLIGATIONS ACCORDING TO THE INTERSTATE COMPACT

Flow in the Rio Grande at Otowi Index Station[1] (ac-ftx1000)	Elephant Butte Effective Index Supply Flow (ac-ftx1000)	(% of Otowi flow)
100	57	(57%)
400	228	(57%)
800	471	(59%)
1200	800	(67%)
1400	996	(71%)
1800	1395	(78%)
2200	1795	(82%)
2300	1895	(82%)

Note 1. See Figure 3.1 for gaging station location.

2. These are summary tables. Complete tables are given in Appendix A.

groundwater rights are more difficult to administer than surface diversions. This development, therefore, contributed largely to the situation whereby junior water rights (the wells) are being allowed to use water, while senior water rights (some with priority dates as early as 1855) are curtailed in order to meet the provisions of a 1937 Compact. Despite a lengthy litigation in the valley in 1979, the practice of curtailing pre-Compact water rights was upheld by the Colorado Supreme Court and remains today the cornerstone of Colorado's efforts to meet its obligations under the 1968 stipulation and the Compact itself. In that trial, rules and regulations for massive water-well curtailment were denied by the court.

Since the Rio Grande Compact is seen as the primary water allocation mechanism in the basin, it must be considered first when predicting where increased streamflow would go if allocated among existing water rights. State laws are essentially secondary to the Compact, since Colorado's stateline delivery obligations are considered to be the equivalent of a senior water right calling for water.

As a result of the recent Colorado Supreme Court decision upholding this situation, it is assumed for the purpose of this report that the water administration that has been evident since the 1968 stipulation will continue into the foreseeable future.

Two Compact administration tables exist for the State of Colorado: one for the Rio Grande mainstem, and one for the Conejos River (see Figure 3.1 and Table 2.1). The courts have ruled that these tables must be applied separately, requiring a separate delivery obligation from each basin. Therefore, for purposes of this study, streamflows and water rights in each basin have been analyzed separately.

For New Mexico, only one table exists (Table 2.2). It essentially applies to the area along the Rio Grande River in between Espanola and the Rio Grande Project in southern New Mexico, consisting of Elephant Butte and Caballo Reservoirs. The Project (Elephant Butte, etc.) delivers water to both southern New Mexico and Texas water users, but because it is so far downstream and comprises a major water allocation point for Texas water divertors, the New Mexico delivery obligation is measured at that point.

Although the early years of Compact administration (from 1968 to the mid-1970's) were somewhat inconsistent, the more recent years have seen a remarkably accurate delivery of requirements, without extreme overdeliveries as was evident in the early years. It is, therefore, appropriate to apply these tables for purposes of this study.

The Rio Grande Compact provides the primary water allocation constraint today. A marginal increase of newly-developed water must first be allocated among the various states in accordance with this interstate Compact before the second level of allocation, which is based on the various state water laws and administrative practices, can be accomplished.

2.2.2 Colorado Water Allocation

Within the Rio Grande and Conejos river basins, the same laws and administrative practices apply. The basic water allocation principle is the "first in time, first in right" rule of the appropriation doctrine. Stated simply, this doctrine establishes a priority system between water appropriators based on the earliest date on which the water was applied to beneficial use. During

times of water shortage, the priority system manifests itself as the senior water rights (those with the earliest dates of appropriation and adjudication) which are able to "call" water from junior water rights (those with later dates).

In an over-appropriated system such as the Rio Grande and its tributaries, some junior water rights get water only in average or wet years or get much-reduced supply in dry years. In general, the more senior the water right, the more dependable it is from a water supply standpoint. The State Engineer, as well as his representative, the Division Engineer in Alamosa, keeps a list of priorities on each river system, from which he administers the water rights (sometimes on a daily basis). A listing of these priorities for the Rio Grande mainstem and the Conejos River is given in Appendix D.

On the Rio Grande and the Conejos, water calls from seniors are regularly used to curtail diversions by juniors. Making adjustments for the Compact first, the Division Engineer and his representatives (the water commissioners) order the curtailment of those water rights diverting to the detriment of either seniors calling for water or the Compact.

The administrative approach described above prescribes a technique for allocating the marginal increase in water supply. A marginal increase of water supply measured at one of the Compact administration index gages can be allocated based on historical records of streamflow, diversions and other parameters such as Compact curtailment procedures. The marginal increase is allocated to a particular water right or group of water rights, corresponding to the junior rights that would be

diverted on a particular day, week or month. In this way, by using the priority list and streamflow records, marginal increases in the water supply can be allocated in a relatively simple, but realistic, manner. By considering other factors such as regional return flow patterns, certain percentages can be applied to simulate the net effect on depletions for a particular level of diversion. In addition, Compact considerations can be applied by using the Compact delivery tables to provide a fixed downstream constraint in accordance with the Division Engineer's administrative policies.

2.2.3 New Mexico Water Allocation

Although New Mexico has similar laws to those of Colorado, some of which are based on the appropriation doctrine, actual water allocation is very different. As the receiving state for Colorado's Compact deliveries, New Mexico is first obligated to deliver a portion of this inflow to the Rio Grande Project, as part of its own Compact delivery obligation. However, the actual curtailment and administration of water rights in between the two New Mexico Compact gages lacks strict priority administration (between Otowi, the upstream New Mexico Compact gage and the Rio Grande Project, the Compact delivery location). This means that for all practical purposes, analyzing individual water rights, as done in Colorado, would not be a meaningful approach in New Mexico.

The primary users of water in between the New Mexico Compact gages are a series of irrigation ditches which comprise the Middle Rio Grande Conservancy District (MRGCD). The most significant administrative practice in this area guarantees that agreements with Indians will be met first. These obligations are generally on the order

of 30,000 ac-ft annually. The remaining water available from Compact administration is allocated according to a rotation system from north to south and east to west throughout the district. The rotation system supplies water in such a manner that even during dry years, no one goes without at least a portion of water (G. Gomez, MRGCD, personal communication).

The existing water allocation practices within the MRGCD suggest that the entire reach of the Rio Grande River in between the two New Mexico Compact gages can be treated as a single entity. This entity which is almost entirely agricultural at the present time, can be analyzed by assigning to it the composite characteristics of the existing distribution of crops, acreages and other parameters that comprise a particular agricultural operation. Thus, the MRGCD may be thought of as if it were a single irrigation ditch for the purposes of this study.

There is currently no competing type of use to interfere with the use of water by the MRGCD. Most of the municipalities in this region use wells for their physical supply, and although most of these involve tributary water (indirectly connected to the Rio Grande), they would not directly benefit from a marginal increase in the surface supply in the Rio Grande itself. In addition, the only major dam in the middle Rio Grande area is Cochiti Dam, a Corps of Engineers project that is primarily used for flood control. Although a minimum pool is used primarily for recreation, this facility is not used directly for irrigation.

2.2.4 Texas Water Allocation

The Compact delivery obligation to Texas primarily manifests itself in the form of deliveries to the Rio Grande Project. As previously discussed, this project, located in southern New Mexico, delivers water to irrigators in both New Mexico and Texas. Water from this project is allocated on the basis of various contracts and operating agreements. Some of the project water (60,000 ac-ft/yr) is allocated to Mexico, to satisfy the international treaty. Under recent administration (1968 to present), no over delivery of water to Mexico has occurred. Return flows and other wastewaters from the project are used to fulfill the Warren Act contract by the Hudspeth County Conservation and Reclamation District in Hudspeth County, Texas.

Allocations to project lands that are irrigated directly from project releases are based on acreage allotments, which are in turn based largely on historical practices as contracted for by several entities in both New Mexico and Texas. These entities include the Elephant Butte Irrigation District in Dona Ana and Sierra Counties in New Mexico and El Paso County Water Improvement District No. 1 (EPCWID #1) in Texas. Due to the urbanization of project land within the boundaries of the City of El Paso, Texas, some of the water is presently being used for municipal supply. However, none of the project water is specifically allocated for municipal use.

Approximately 5,000 acres have been acquired and dried up by the City of El Paso (out of the total 160,000 irrigated). Based on this, it is estimated that actual municipal use of project water amounts to about three

percent of the present allocation of water from the project. This same percentage can be applied to what is left from the marginal increase in water supply after Colorado and New Mexico have used their share. Since the amount of water left after the agricultural allocations in the two upstream states is small, it is anticipated that, in an average year, approximately one percent of the original marginal increase in flow at the Del Norte gage would get as far as El Paso to be allocated to municipal use. A considerable amount of water is allocated before this under current conditions of water allocation in the Rio Grande River basin. Since El Paso appears to be the final significant entity capable of having any appreciable impact on the study from a dollar value standpoint, there is no reason for continuing the study beyond this point.

2.3 Current Water Demand and Utilization in the Rio Grande System

In order to understand the use of any incremental flows occurring in the Rio Grande River basin, the demands for water (both base and incremental flow) in the previously discussed regions have been evaluated. Data for these evaluations were taken from conservancy district and project summary reports. Agencies were contacted where published data was lacking (typically the case in all regions). A summary of the most pertinant available data is given below.

2.3.1 Colorado

The extensive system of canals and pre-Compact reservoirs in Colorado has a large distribution capacity. The operation of the canal system has been refined in recent years so that, for all practical purposes, Colorado receives its maximum allotment of water under

the constraints of the Compact. The following information was obtained from the Water Division No. 3 Engineer in Alamosa (Steve Vandiver, personal communication).

Water use in the San Luis Valley is principally agricultural. Approximately 5 percent of all diversions are for municipal or domestic use (average annual). There are no major industrial uses of surface water in the valley. Municipal use of surface water consists of the towns of Creede (water diversion from Willow Creek), Antonito, and Del Norte (for lawn watering only). Population in the valley has been holding steady and no additional major surface water use by municipalities or industry is anticipated in the near future.

Water diversion for purposes of agricultural irrigation generally begins between April 10 and April 15. Extensive negotiations have occurred in this region to minimize diversion prior to this data in all but very dry, warm spring seasons. Current administrative policy calls for all normally divertable early spring runoff (i.e. runoff between the first of March and mid-April) to be used to meet Compact delivery requirements. Diversions that begin during mid-April are based upon early season snowpack and estimated runoff forecasts. During this period, the maximum possible diversions are made. The final snowpack and estimated runoff data obtained during the first week in May are then used to establish curtailment levels required to meet Compact delivery requirements for the period of May 1 to November 1. The curtailment levels established at this critical time are then administered on a daily or twice-daily basis until July 1 when curtailments are re-evaluated. If an adjustment in the curtailment level determined in May is desirable, all subsequent diversions from July 1 to the end of the irrigation season in early fall are changed accordingly.

if juniors to get only one water strong seniors must not be diverting.

The system of canals on the Rio Grande mainstem in Colorado is capable of diverting up to 5,000 cfs for a maximum period of 10 days. It should be noted that the data base given in Appendix D indicates water right filings in excess of 9,100 cfs on the Rio Grande mainstem. The demand for water from the mainstem significantly exceeds the current ability of the system to supply water. This is also the case on the Conejos River.

During the peak runoff period which generally occurs sometime from mid-May to mid-June, additional "effective" diversion capacity is available through storage in the upstream pre-Compact reservoirs (Rio Grande, Continental, Santa Maria, and Beaver Park). The equivalent diversion capacity of these pre-Compact reservoirs under ideal conditions is approximately 2,000 to 2,350 cfs. It should be noted that all other reservoirs in the upper basin area (i.e. Road Canyon Reservoir #1, Big Meadows, Rito Hondo, Alberta Park, and Platoro) are post-Compact reservoirs which cannot be used by Colorado for Compact administration purposes. These reservoirs are used to hold transmountain diversions or for flood control purposes only. The capacity of these pre-Compact reservoirs under ideal conditions is approximately 2,000 to 2,350 cfs.

The following discussion illustrates how the system is operated during extreme wet periods when the likelihood of marginal increases not being used is highest. During the peak runoff period, flows at the Del Norte gage are monitored very carefully. If for example, peak flows are measured as 8,000 cfs and a 20-percent curtailment has been established based upon the May 1 snowpack and runoff estimates, the Water Division No. 3 engineer would operate the system as follows:

why not just overdeliver to NM(?)

(a) Total flow = 8,000 cfs

(b) Compact Curtailment (20% of total baseflow) = 1600 cfs (estimate)

(a)-(b) Possible Colorado diversions = 6400 cfs

(c) Actual Canal Diversions = 5000 cfs

(d) Reservoir Storage (out of priority) = 1400 cfs

(c)+(d) Actual Colorado Diversions = 6400 cfs

As mentioned earlier, the Division Engineer can operate the system in this manner for a period of up to 10 days. Thereafter, the farmers must begin to shut down diversions onto their lands to prevent flooding. However, only twice during the past 13 years has the engineer not been capable of diverting the total estimate Colorado allotment during the peak runoff period. This has occurred only when peak runoff flows have been in excess of 8,000 cfs at Del Norte. As illustrated by the monthly flow summary presented in Table 5.4, this is an extremely rare event.

good point

As can be seen from the preceding discussion, the demand and administrative policies of Colorado have the capacity to fully utilize Colorado's Compact allotment. Only during extreme wet runoff periods do physical system limitations prevent estimated allotments from being captured and utilized for benefical use, either immediately or by later season releases from upstream reservoirs. Even if this occurs, the accounting measures employed by the Water Division No. 3 Engineer would result in later season adjustments to curtailment levels to meet Compact delivery requirements. The net result is in effect, utilization of the early season runoff water by increased late season diversions.

For all practical purposes, incremental runoff as evaluated for these studies can be utilized by the State

of Colorado to its full benefit under Compact constraints. The values of incremental runoff as described in Section 2.4 do not begin to significantly encroach upon the unfulfilled demand or diversion capacity that currently exists in the San Luis Valley of Colorado.

The implementation of the Closed Basin Project (see Section 4.2. for detailed description) in Colorado beginning in 1985 is not anticipated to significantly affect the administrative policies of the Water Diversion No. 3 Engineer. The total peak capacity of this project will be 150 cfs. As can be seen from the preceding discussion, during peak runoff conditions, the Closed Basin Project is only 2 percent of the total potential Colorado diversions (i.e. for the preceding example where Colorado diversions total 6,400 cfs). It is highly unlikely that the project will be operated during peak runoff periods. Even if this were to occur, the Water Division No. 3 Engineer believes it would not result in any changes in the way the system is currently operated or in Colorado receiving its full Compact allotment of water.

2.3.2 New Mexico

The Middle Rio Grande Conservancy District (MRGCD) consists of a total of 121,000 acres of which 89,700 are currently irrigated for agricultural purposes. The principal crops include alfalfa (over 40,000 acres), and silage (5,000 acres). Other crops, including apples and grapes, comprise the remaining irrigated acreage. Irrigation water is obtained principally from the Rio Grande mainstem. The district receives 20,000 ac-ft of water annually from the San Juan-Chama Project. No year-

to-year carry over of this water is permitted. The district also holds the right to store and use an additional 60,000 to 70,000 ac-ft of water from the San Juan-Chama Project if and when the State of New Mexico's debt to Texas is payed back, or if Elephant Butte Reservoir ever spills in the future. These conditions, for all practical purposes, eliminate the possibility of additional San Juan-Chama water being used for agricultural purposes by the district in the foreseeable future (B. Grano, USBR, personal communication).

Water diversions begin in the district during March and generally continue until November. A summary of annual water availability and use in the district is given in Table 2.3. This information was taken from the Rio Grande Compact Commission Reports (1968-1982). Colorado delivers an average of 312,000 ac-ft of water to the state line every year (1968-1982). This is approximately 34 percent of the mean annual flow measured at the Otowi Index Supply station (see Figure 3.1). This data indicates that the mean annual tributary flow that occurs from the upper New Mexico basin area is 600,000 ac-ft. The data also indicates that approximately 66 percent of the flows measured at Otowi are delivered to Elephant Butte to meet Compact requirements. Consequently, 34 percent of the water measured at Otowi can be used within the district. The records indicate that New Mexico actually delivered 68 percent of the Otowi index supply for the period 1968 to 1982. This represents a use of 32 percent.

The information given in Table 2.3 also shows some interesting trends. For the period of 1968 to 1975, the district reports an average under-utilization of 22 percent of available water. This corresponds to a mean annual use of 258,000 ac-ft compared to an available supply of 316,000 ac-ft. For the period from 1976 to

1982, the district reported an average annual over-utilization of 8 percent. During this period, 322,000 ac-ft were diverted when only 296,000 ac-ft were determined to be available according to the Compact. Overall, the district shows an average annual under-utilization of 7 percent for the entire period.

This information suggests that the administrative practices of the district have been refined in recent years to maximize the use of available waters. The maximum annual net demand for water is between 2 to 3 ac-ft/ac (G. Gomez, personal communication). Water use records from the district show that actual water delivery to the farms is 30 to 40 percent of the gross diversions from the Rio Grande River. Sixty to 70 percent of the supply is consumed by operational spills and transportation losses. Reliable information on the amount of return flow to the Rio Grande from the MRGCD could not be found. Information from the district suggests that it is not very significant (G. Gomez, personal communication). For purposes of this study, therefore, it is assumed that only 35 percent of gross diversions are beneficially used within the district. It is furthermore assumed that return flows are negligible.

Considering a net demand of 2 ac-ft/ac, and excluding Indian requirements and demands met by the San Juan-Chama Project, and incorporating the 65 percent losses, the district has a total gross annual diversion requirement of approximately 523,000 ac-ft from the Rio Grande River. With an application rate of 3 ac-ft/ac, the gross annual diversion requirement would be 779,000 ac-ft. Data presented in Appendix B show that incremental flows would result in an additional allotment of up to 24,000 ac-ft (100-percent treatment level, 1970) to the Middle Rio Grande Conservancy District. The data in Table

TABLE 2.3

SUMMARY OF WATER AVAILABILITY AND UTILIZATION

IN THE NEW MEXICO - MIDDLE RIO GRANDE CONSERVANCY DISTRICT

(ALL VALUES IN AC-FT X 1000)

Year	Colorado Deliveries @ Lobatos	Adjusted New Mexico Flows @ Otowi Index Supply	N.M. Delivery to Elephant Butte: Approximate Required Delivery	N.M. Delivery to Elephant Butte: Actual* Delivery	N.M. Use: Water Available for Use	N.M. Use: Actual Use
1968	330.8	870.6	521	604	349	267
1969	415.1	1,167.2	770	882	397	285
1970	323.5	832.2	494	525	338	307
1971	206.8	566.1	325	368	241	198
1972	162.3	474.3	271	425	203	49
1973	520.7	1,576.3	1,171	1,098	405	478
1974	121.5	450.4	257	306	193	144
1975	466.7	1,185.8	787	850	399	336
1976	249.0	682.5	395	379	288	304
1977	61.2	296.5	169	202	128	95
1978	174.5	699.0	405	378	294	321
1979	625.8	1,888.7	1,484	1,382	405	507
1980	451.7	1,392.2	988	967	404	425
1981	131.5	416.9	238	188	179	229
1982	439.7	1,183.5	785	810	399	374
Mean Annual=	312	912	604	624	308	288
			66	68	34	32 %

*Actual effective supply as determined by Compact requirements.

2.3. show a maximum water availability of 405,000 ac-ft for current conditions. Comparing demands to actual net supplies over the period from 1968 to 1982 shows an average shortfall in excess of 200,000 ac-ft. Although agricultural demands are not expected to increase (McDonald et. al., 1982) over the next 10 years, the current demand is sufficient enough to utilize all incremental volumes determined for the 1968 to 1982 period that would be allotted to the district.

2.3.3 Texas

The total amount of land serviced by the Rio Grande Project is about 178,000 acres. Water rights are allocated to about 160,000 acres of which 91,000 acres (57%) are located in New Mexico and about 69,000 (43%) in Texas. The project is authorized for agricultural use only, and to release a maximum of 3.04 ac-ft/ac annually.

Crops include vegetables (mainly peppers), miscellaneous field crops (including most notably, cotton), cereals (including barley, sorghums, and wheat), forage (alfalfa, other hay, irrigated pasture, and silage or ensilage), and pecans. The gross crop valuation in 1979 was estimated as $97,832,000 for 133,415 acres for an average return of $733.29 per acre. Note that approximately 26,600 acres were not irrigated during 1979 as part of the project land rotation schedule and water supply projections. At the upper end, the total vegetable crop was valued at $42,680,000 for 20,362 acres for an average return of $2,096 per acre. A gross valuation of $24,062,000 was estimated for 61,268 acres of miscellaneous field crops, for an average return of $392.74 per acre (USBR, Rio Grande Project History, 1979).

During 1979, a total water delivery of 309,721 ac-ft (including 13,518 ac-ft to the City of El Paso) was recorded for the project. This was the first year that the maximum possible allotment was made available (i.e. 3.04 ac-ft/ac) to members of the district. Although the maximum allotment was available, the average application during 1979 was 2.32 ac-ft/ac. A total release of 569,000 ac-ft was required to achieve the delivery of 309,721 ac-ft. Subtracting the delivery requirement to Mexico (60,000 ac-ft), indicates that losses amount to 199,279 ac-ft which are over 39 percent of the total release. The USBR estimates the average annual conveyance losses are approximately 34 percent (B. Cortez, USBR, personal communication). Information from the city of El Paso (Doug Rittman, personal communication) indicates that the average allotment of water until recently (1979-1983) has been approximately 2 ac-ft/ac.

good

The maximum annual release from the project reservoirs (Elephant Butte and Caballo) is governed by contractual and legislated agreements. Theoretical maximum annual release values are as follows:

Authorized to service		159,600 acres
Authorized maximum application		3.04 ac-ft/ac/yr
Total delivery	=	485,336 ac-ft/yr
Estimated system losses (34%)	=	244,664 ac-ft(max)
Mexico treaty release requirement	=	60,000 ac-ft/yr
Total allowable maximum annual release	=	790,000 ac-ft

Over the past 30 years, the project has not released the maximum amount given above. This is due mainly to problems with Compact administration (pre-1968), as well as the relative dry cycle which was occurring up until 1979. Since 1979, the project has been making maximum

allotments available for delivery. The maximum application rate has not always been achieved, or has been applied to reduced acreages. This has resulted in a continuing trend of total releases below the maximum allowable release of 790,000 ac-ft.

Inflows to Elephant Butte Reservoir since 1976 have been as follows (USBR, Mr. Burt Cortez, personal communication):

Year	Total Inflow (ac-ft)
1976	458,300
1977	224,400
1978	417,700
1979	1,555,000
1980	1,218,000
1981	262,600
1982	921,000
1983	1,186,000
Mean Annual Inflows 1968-1983	780,375

As a result of the large inflows that have occurred since 1979 (average annual inflow = 1,028,520 ac-ft for period 1979 to 1983), water levels in Elephant Butte Reservoir have risen to a current level (as of February, 1985) that is 77 percent of capacity. This corresponds to a current storage of 1,624,930 ac-ft with additional capacity for 485,370 ac-ft. A rough water balance calculation of inflows, outflows and net change in storage between 1979 and 1983 indicates that annual reservoir losses due to evaporation and seepage range from approximately 350,000 ac-ft when the reservoir storage is 1,000,000 ac-ft to over 400,000 ac-ft for the reservoir at its current capacity. A significant portion of these losses are due to evaporation. The mean annual precipitation at the dam is 10 inches. The mean annual estimated total lake evaporation at the dam is 77 inches.

This corresponds to a net, mean annual lake evaporation of approximately 67 inches (5.6 ft). With the reservoir at a capacity of 1,000,000 ac-ft, an average annual inflow of 1,028,520 ac-ft would experience evaporation losses of approximately 137,000 ac-ft (14 percent). Total losses including evaporation and seepage would be approximately 350,000 ac-ft (35 percent). Because of carryover considerations at higher reservoir levels, additional evaporation and losses in the reservoir will serve to deplete the overall "useable" inflow. Likewise, inflows at lower reservoir levels will experience reduced loss rates. For purposes of this study, a reduction in useable inflows of 35 percent is assumed to be the average over the selected hydrologic period discussed in Section 2.5. When considering these evaporation and seepage losses, as well as other conveyance losses after release (i.e. 34 percent) delivered water is approximately 48 percent of original inflows to Elephant Butte.

The preceding information indicates that the combined capacity of the Elephant Butte Reservoir, along with considerations of Rio Grande Project losses and agricultural water use create a maximum gross annual water demand in excess of 1,000,000 ac-ft. The mean annual inflows to Elephant Butte Reservoir for the period 1968 to 1983 were 719,870 ac-ft. This corresponds to an existing total annual demand shortfall in excess of 280,130 ac-ft. Average annual marginal streamflow increases in excess of 280,000 ac-ft would be required to completely satisfy this demand.

Another consideration of the Rio Grande Project is hydropower generation. The plant capacity at the base of the Elephant Butte dam is 24,300 KW. All water seasonally

released from the dam for irrigation is used to generate hydroelectric power. In 1979, a total release of 554,000 ac-ft resulted in the generation of 67,813,400 KWH, or an average of 122.4 KWH/ac-ft. Revenues from the sale of this electricity averaged $0.013 per KWH.

2.4 Future Development

Although most of the present municipalities along the Rio Grande would not benefit from a marginal increase in the surface supply in the river, certain conditions could change this in the future. These are discussed below.

The foregoing discussion of the existing legal and administrative framework indicates that marginal increases of water would be allocated to existing water rights according to normal administrative practices. Appropriation of marginal water in Colorado would, consequently, be by priority. In the MRGCD, marginal water would be appropriated by percentage of use that is consistant with current allocations. Similarly, in the Rio Grande Project, marginal water would be appropriated as a percentage of current use. Under the current administrative practices, changes in municipal allocation would occur only as a result of the development of unexpected demands, supply shortfalls, or the influence of cost factors. Under the present allocation system, prospects for significant water allocation to other than agricultural uses are rather poor.

An additional consideration is the potential administrative changes that are being pursued by the City of El Paso to obtain a more direct supply of Rio Grande project water. Under current contracts and legislation governing water arrangements between the USBR and the Rio Grande project water users, El Paso can only obtain water for municipal use by purchasing agricultural water shares and then taking irrigable acreages out of service.

The principal consideration in this issue is the fact that additional water use from Elephant Butte would impact on the time required for the reservoir to fill and subsequently spill. This additional use could, therefore, affect the date on which Colorado and New Mexico are relieved of their current debt under the Compact.

In spite of these inherent difficulties, El Paso is continuing to pursue legal alternatives. Because of growing demands, pressure will continue to rise to find a solution to municipal water demands in the El Paso area without injury to productive agricultural lands (see Section 2.7.5 - Texas). As a result, administrative changes could occur in the foreseeable future. If this were to occur, marginal flows could be utilized for municipal purposes in proportion to current releases from the project without affecting current agricultural use and production. As subsequently discussed, (Section 2.7.5), municipal use could increase to as much as 6 to 8 percent of the total annual releases from the Rio Grande Project by the year 1999.

Alternatively, it is conceivable that an effort could be made to obtain a court ruling to consider the marginal increase flows as a result of silvicultural activity to be "special," such as nontributary or developed water. Although these prospects are remote, they represent a finite possibility that should be considered in a study of this type. In order to evaluate this potential, it is necessary to speculate what could happen to the distribution of this water if it could be done outside of the present water allocation system. The subject of developed water is highlighted in the case Southeastern Colorado Water Conservancy District vs. Shelton Farms, Inc., (Colo. 1974), and the three very recent decisions of the Colorado Supreme Court, dated September 10, 1984, (Griffen vs. State of Colorado, Southeastern Colorado Water Conservancy District vs. The City of Florence, and CF&I Steel Corporation, and RJA, Inc. vs. Water Users Association

of District No. 6). These cases provide insight into how this water could be ruled to be developed under the present judicial interpretation of existing law.

With an allocation based on control and direction, marginal increases could be allocated to "higher and better" uses such as municipal or industrial. This would require some major changes in the present water laws of the various states, as well as a recognition by all states under the Compact that the water is, indeed, developed and was not previously depended upon by any existing water users. The incentive for this kind of recognition by existing water users is not apparent today. However, to the extent that such control of the marginal increase in runoff could be achieved, it could be allocated to more economically beneficial uses than irrigation.

2.5 Hydrology

The economic evaluations, recommendations, and conclusions presented in subsequent sections are based upon model studies of the Rio Grande River basin over a 15-year simulation period. The period selected was the most recent, i.e. 1968-82. This period represents rigid enforcement of the Compact in Colorado and also includes the most comprehensive data base. The following information is a summary of the baseline data, methods of predicting increased streamflow, and synthesis of increased streamflow volumes used in model studies.

The baseline precipitation data, as well as estimates of the incremental runoff increases and timing of this runoff from manageable areas of the National Forest, were provided by the USDA. Data on streamflow records and estimates of the volume of runoff were performed under the terms of the contract by SRK.

2.5.1 Baseline Hydrologic Data

Streamflow in the Rio Grande River is largely derived from precipitation and snowmelt in the high mountain areas of the upper catchment basin in Colorado (see Figure 2.1). Typical average annual hydrographs are shown in Figure 2.2 and clearly demonstrate the impact of snowmelt in the May-June period and the limited amount of additional streamflow that occurs in the lower Rio Grande basin.

2.5.2 Statistical Analyses of Hydrologic Data

A series of statistical analyses were performed in order to determine the range of climatic conditions included in the baseline data (1968-82). Data from two gaging stations were analyzed to develop frequency plots of runoff. Station 2195 is located on South Fork Creek approximately 12 miles upstream of Del Norte (see Plate 1). This gage is on an unregulated stream and reflects runoff from a relatively undisturbed watershed with a northeast aspect. The other gage selected was number 2200 at Del Norte. This is the principal gage for Compact administration and reflects runoff from a large watershed with north to south aspects. Several reservoirs are located high above this gage which could have a minor effect upon the streamflow.

Streamflow records from 1910 to 1982 (72 years) for station 2195, and from 1890 to 1982 (92 years) for station 2200 were used to develop the frequency plots and to estimate statistical recurrence intervals of streamflows between 1968 and 1982. As the principal increased runoff will occur during the spring (April, May, and June) period, the flow volumes for this period only were used in the analyses.

The frequency plots for stations 2195 and 2200 are given in Figures 2.3 and 2.4. Figure 2.3 is a summary of wet season streamflows expressed as a fraction of the mean. Likewise, Figure 2.4 is a summary of the dry season flows expressed as a fraction of the mean. These figures indicate that the most extreme wet and dry snowmelt runoff of record occurred during the selected simulation period.

The wettest snowmelt runoff in the 1968-82 record occurred during 1979. Figure 2.3 indicates that this runoff has an estimated recurrence interval of 1 in 85 years. The driest period of runoff in the record occurred during 1977. Figure 2.4 indicates that this has an estimated recurrence interval of approximately 1 in 130 to 150 years. Incorporating these extreme events into the model studies and economic evaluations will, therefore, allow an annual net benefit projection from a realistically wide range of climate conditions.

2.5.3 Methodology for Predicting Runoff Increases

Extensive work has been completed by the U.S. Forest Service to estimate runoff increases (for example, Troendle and Leaf, 1980) due to silvicultural activity. The estimates of runoff increases for these studies, as shown on Figure 2.5, were based upon the physical basin information given in Table 2.4 (from USDA) and; 1) the computerized version of WRENSS[1] called WET, 2) USGS and USFS records and maps, and 3) expert judgement. The estimated runoff increases are based on 100 percent treatment which involves removal of 50 percent of the forest cover and maintenance of this cutback. The time distribution of the increased runoff was also provided by the USDA and is shown in Figure 2.6.

[1]Acronym for an approach to Water Resources Evaluation of Non-Point Silvicultural Sources (USDA Forest Service, 1980).

With this information, actual runoff volume estimations for the model studies were developed as follows:

1) Precipitation data for the simulation period at the Hermit 7 ESES precipitation recording station was gathered (Station shown on Figure 2.1, annual precipitation summarized on Figure 2.7).

2) Data for the individual sub-basins within the Rio Grande National Forest used by the USDA to estimate runoff increases were lumped into regional basins.

3) Precipitation in each regional basin was estimated based upon the Hermit 7 ESE station and the elevation versus average annual precipitation relationship was developed for the upper basin (Figure 2.8).

4) Total increased runoff volumes were estimated based upon the manageable acres within each regional basin.

5) Total increased runoff volumes were then distributed over the spring runoff period according to the runoff distribution curve.

The individual sub-basins listed in Table 2.4 are shown on Figure 2.9. Table 2.4 summarizes the base data on each individual basin. The normal annual precipitation values in this table were derived from the weather bureau map reproduced on Figure 2.1 (also shown on this figure is the Hermit 7 ESE precipitation measurement station). Table 2.5 summarizes how the catchment areas were lumped.

TABLE 2.4

BASE DATA FOR ESTIMATIONS OF RUNOFF INCREASES

Watershed Designation	Mean Elev. (ft)	Aspect	Catchment Area		Normal Annual Precip (inches)
			Non-Manageable (Wilderness) Acres	Manageable Acres	
4E	9,900	NE 1.5	-	45,482	20
4F	9,100	SE 2.5	-	6,911	19
4G	10,100	SW 2.5	-	10,154	24
4H	10,500	S 3	-	18,709	25
4I	9,300	SW 2.5	-	7,146	20
4J	10,100	W 2	-	8,554	25
4K	10,400	SW 2.5	-	37,525	26
4L	9,800	S 3	-	11,519	21
4M	11,200	SW 2.5	-	26,858	30
4N	11,100	SE 2.5	-	23,701	28
5A	10,500	E 2	-	11,989	25
5B	9,900	E 2	-	7,061	22
5C	9,700	SW 2.5	-	5,866	22
5D	9,200	SW 2.5	-	6,335	20
5E	10,800	SW 2.5	-	9,151	28
5F	11,000	SW 2.5	-	4,607	29
5G	11,400	W 2	-	19,349	33
5H	11,100	S 3	-	41,962	28
5I	10,600	SE 2.5	-	16,661	25
5J	10,000	NE 1.5	-	20,266	22
5K	10,200	S 3	1,304	5,714	23
5L	11,800	SE 2.5	-	17,023	33
5M	11,300	SE 2.5	-	7,935	29
5N	11,900	SE 2.5	-	15,082	34
5P	12,000	E 2	5,286	3,524	34
6A	11,700	NE 1.5	-	5,461	31
6B	11,400	N 1	8,063	-	28
6C	11,200	NE 1.5	25,727	-	27
6D	11,000	NE 1.5	9,493	-	26
6E	11,400	W 2	14,122	-	33
6F	11,100	W 2	11,967	-	31
6G	10,300	NW 1.5	4,434	493	24
6H	11,200	N 1	7,218	1,805	27
6I	10,100	NE 1.5	-	11,306	22
6J	10,900	NE 1.5	17,666	7,571	26
6K	10,700	N 1	9,950	14,924	24
6L	10,300	NW 1.5	-	13,290	24
6M	9,200	W 2	-	6,847	20
6N	9,700	N 1	-	2,751	20

TABLE 2.4 (con't)

BASE DATA FOR ESTIMATIONS OF RUNOFF INCREASES

Watershed Designation	Mean Elev. (ft)	Aspect	Catchment Area (Non-Manageable) (Wilderness) Acres	Catchment Area Manageable Acres	Normal Annual Precip (inches)
7A	10,200	W 2	-	10,602	26
7B	9,500	NE 1.5	-	4,970	20
7C	10,600	NE 1.5	39,090	21,048	25
7D	9,300	NE 1.5	-	4,650	19
7E	9,800	E 2	-	11,263	21
7F	10,000	E 2	-	14,667	22
7G	9,200	N 1	-	5,930	18
7H	10,300	E 2	-	4,501	24
7I	10,300	E 2	10,981	32,944	24
7J	10,500	E 2	-	26,175	25
7K	10,300	NW 1.5	-	31,253	24
7L	9,400	NW 1.5	-	6,293	20
7M	10,000	N 1	-	12,053	22
7N	9,800	NE 1.5	-	4,693	21
7N	9,800	N 1	-	6,890	21
7N	9,700	E 2	-	4,991	21
8A	8,900	E 2	-	13,375	18
8B	10,800	E 2	-	15,317	26
8C	10,500	N 1	-	13,375	23
8D	10,300	E 2	-	12,095	23
8E	8,700	N 1	-	4,735	16
8F	10,000	NE 1.5	-	13,589	22
9D	9,700	E 2	-	16,661	21
9E	9,600	NE 1.5	3,558	14,233	20
9F	10,900	E 2	24,523	33,866	27
9G	10,800	E 2	29,333	-	26
9H	10,900	E 2	4,607	-	27
9I	10,800	NE 1.5	18,950	8,121	25
9J	9,400	E 2	-	3,434	20
9K	10,200	E 2	-	6,357	23
9L	9,500	NE 1.5	-	7,637	20
9M	8,900	NE 1.5	-	4,927	18
9N	9,200	E 2	-	8,831	19

Note: Watershed designations shown on Figure 2.9 were determined by USDA for purposes of estimating normal annual precipitation. Other data in table is typical of that required, and used by the USDA to determine the runoff increase relationship given in Figure 2.5.

TABLE 2.5

SUMMARY OF REGIONAL BASIN DATA

Overall Regional Basin Designation	Individual Contributing Sub-basin[2]	Total Manageable[1] Contributing Acreage for Increased Runoff Calculations (acres)	Average Regional Basin Elevation (ft)
Rio Grande Reservoir	5(K,L,M,N,P), 6(A,B,C,D)	49,280	11,580
Continental Reservoir	(0.75)·5H	31,470	11,100
Santa Maria Reservoir	(0.25)·5H, 5(E,F,G)	43,600	11,160
Del Norte Gage	4(E,F,G,H,I,J,K,L,M,N) 5(A,B,C,D) 6(G,H,I,J,K,L,M,N) 7(A,B,C,D,E,F,G,H,I,J,K,L,M,N)	514,765	10,241
Platoro Reservoir	(0.40)·9F	13,545	10,900
Mogote Gage	(0.60)·9F, 9(D,E,G,H,I,J,K,L,M,)	81,490	10,075

[1]Manageable acres as determined by USDA and shown on Table 2.3.

[2]Fractions of sub-basins are required for accounting purposes. For example 0.4 times the total manageable acreage of sub-basin 9F flows into Platoro Reservoir and 0.6 times the area of sub-basin 9F flows into the stream below the reservoir.

Further total runoff volume estimates were carried out by using 10- and 50-percent treatment levels (i.e. 5- and 25-percent forest removal). These were pro-rated from the 100-percent treatment level runoff volumes assuming direct proportionality between runoff increase and treatment level. A summary of these runoff calculations is given in Appendix B.

2.6 Compact Allocations

Compact allocations of increased streamflow were calculated for each time period of the overall modeling time frame. The Compact allocations were based upon total annual baseflows at the Del Norte, Labatos, Lasauses, and Mogote streamflow gages in Colorado and the Otowi and Elephant Butte Index Supply gages in New Mexico. The Del Norte and Lobatos gages are the basis of the inflow-outflow relationships for the Rio Grande mainstem and the Mogote and Lasauses gages function similarly for the Conejos in Colorado. Calculations were completed according to the following procedure:

Colorado-New Mexico

1) Total annual flows at the Del Norte and Mogote gages, as well as actual Compact deliveries, were developed for each year of the overall modeling time frame from the annual reports of the Rio Grande Compact Commission;

   Total base flow at station = A_i
   Compact delivery = D_i

   where i = simulation year (1968 to 1982)

2) Increased flows (B_i) as discussed in the preceding section were then added to the total baseflow to determine a revised total annual flow ($A_i + B_i$). A calculated Compact delivery

obligation (C_i) from Colorado to New Mexico was then estimated from the Compact tables for each of the revised total annual flow values ($A_i + B_i$).

3) Annual Compact allocations (E_i) for the increased streamflows (B_i) were then calculated:

$$E_i = C_i - D_i$$

4) The E_i increased streamflow quantities represent water delivered from Colorado to New Mexico. The difference $B_i - E_i$ is increased streamflow which would be distributed within Colorado.

5) The Compact allocation value E_i was then distributed on a weekly basis according to the cumulative distribution curve given on Figure 2.6.

New Mexico - Texas

1) Total annual base flow F_i at the Lobatos gage was developed for each year (i) of modeling time frame from annual reports of the Rio Grande Compact Commission.

2) Annual Compact delivery from New Mexico to Texas (G_i) was then estimated from Compact delivery tables for the total flow value $F_i + E_i$. The estimated G_i value is the amount of increased streamflow which would be delivered to the Rio Grande Project below Elephant Butte Reservoir.

3) The amount of increased streamflow water delivered to the Middle Rio Grande Conservancy District was then determined as;

$$E_i - G_i$$

4) The above Compact allocation values were then distributed on a weekly basis according to the distribution given on Figure 2.6.

A summary of these calculations for each weekly time increment of the overall modeling time frame, for each level of silvicultural treatment is given in Appendix B.

2.7 Value of Water

2.7.1 Introduction

This section discusses the value of water use in the study area as obtained from a feasibility-level survey of available information. An in-depth determination of more accurate values is beyond the scope of this study.

It should be noted that the results of the feasibility-level survey do not provide accurate enough information to develop different agricultural water values for the various regions (established for modeling purposes as discussed in Section 3.1) within Colorado. Results showing water volumes allocated to the various regions are presented in subsequent sections in the event that future economic evaluations determine more accurate regional water values.

Accurate determination of water values for agricultural, municipal, and industrial uses in Colorado, New Mexico, and Texas will require a more detailed evaluation of today's market conditions, and as projected into the future. Such a detailed study would only be warranted if these preliminary studies indicate that silvicultural treatment is economical. The more accurate assessment of water values would be required in order to optimize the degree of treatment to be introduced.

2.7.2 Approach and Results

Two methods were used to place approximate values on water use for this study. The first method involves developing detailed crop budgets for the major crops in the San Luis Valley, i.e. potatoes, barley, wheat, and hay. The crop budgets for the San Luis Valley were assumed to be representative of the majority of crops in the MRGCD, as well as the estimated value of water. Development of detailed crop budgets for the major crops of the MRGCD, i.e. alfalfa (45% of total irrigated in 1984), silage (6%) and other miscellaneous items such as wheat, other hay, apples, grapes, etc. (49%), was, therefore, not completed.

Comparing the revenue with the marginal costs of producing these crops provides a net crop value. This value is then divided by the gross irrigation application to determine the water value. The resulting average for all crops, excluding potatoes, is $7/ac-ft/yr.

Potatoes are the highest value crop in the valley. All water required by potato crops has generally been provided by reallocation from the lower value crops. Expansion of the potato crop is, therefore, not dependent on additional water, but on availability of suitable land and financing (D. Steinhart, personal communication). The potato crop value is, therefore, not a true reflection of the economic value of water and is excluded from the analysis.

The second method used to develop a water value was to interview senior water management officials in city and regional governments. As a result of these efforts, it is estimated that agricultural water was worth approximately $8/ac-ft/yr in New Mexico, and $30/ac-ft/yr

in Texas. Municipal and industrial water is valued at approximately $40/ac-ft/yr in New Mexico, and $30/ac-ft/yr in Texas.

The approaches used are discussed in more detail below.

2.7.3 San Luis Valley Crop Budget

The preliminary work done by the USDA (Appendix C) was reviewed and expanded as outlined below. Costs for selected crops in 1983 were obtained from the San Luis Valley Farmers Ranch Management Association (D. Steinhart) and are shown in Table 2.6. These costs were separated into fixed and variable cost categories. For purposes of this study, it is assumed that only the variable farm costs, i.e. those directly attributable to cultivation, would apply to the use of an increased amount of irrigation water. Because of the relatively small percentages of increased water supply, it is not believed that the farmers would have to expand their facility and equipment fleets. It is assumed that the large majority of farmers do not currently irrigate all land available to them and that the additional water could easily be used by slightly increasing irrigated acreage.

I don't agree. Pun is here

Information for 1983 on crop yields per acre and crop prices were obtained from the Colorado Agricultural Statistics and are shown in Table 2.7. In order to eliminate the effect of annual price fluctuations, a graphical "smoothing" of the prices was undertaken as shown in Figure 2.8. Prices interpolated for 1983 from the smoother curve are more representative of average conditions and were transformed to Table 2.7.

TABLE 2.6

1983 COST DATA FOR SELECTED CROPS IN $/acre

Cost Items	Crop Types			
	Potatoes	Barley	Wheat	Hay
Variable Costs				
Fertilizer	86	39	47	0
Chemicals	35	13	10	0
Seed storage and other costs	129	22	12	5
Utilities	9	5	4	4
Machine repairs	75	28	22	21
Machine hire	14	33	38	14
Fuel oil	34	20	15	11
Irrigation	51	46	52	25
Auto	1	1	1	1
Labor	62	23	23	10
Miscellaneous	8	6	5	5
Cash Rent - L.L. Costs	49	18	44	5
Insurance	12	9	9	3
Taxes	20	17	12	4
Subtotal Variable Costs	585	280	294	108
Fixed Costs				
Interest	108	60	55	36
Building Repair	2	3	1	0
Machinery Depreciation	70	11	11	11
Building Depreciation	25	4	4	4
Subtotal Fixed Costs	205	78	71	51
Total Costs	790	358	365	159

TABLE 2.7
CROP BUDGET

Crop Type (1)	1983 Irrigated Yield per acre (2)	1983 Standardized price - $ (3)	Variable Production cost $/acre (4)	Marginal Income $/acre .95x(2)x(3)-(4) (5)	Gross Irrigation Application ft. (6)	Marginal Value of Water $/acre-ft (5)/(6) (7)	1983 Total Production in San Luis Valley (8)	1983 Total Value in San Luis Valley $ (9)
Potatoes	283 Cwt	4.5/Cwt	585	624.8	3.5	178.5	32.2 million Cwt	145 million
Barley	100 Bu	3.1/Bu	280	14.5	5.0	2.9	9.5 million Bu	30 million
Wheat (Spring)	95.5 Bu	3.6/Bu	294	32.6	5.0*	6.5	3.1 million Bu	11 million
All Hay	2.15 Tons	67.0/Ton	108	28.8	2.5	11.5	454,000 Tons	30 million
					Weighted average:	$ 7.1/acre-ft (excluding potatoes)		216 million

Gross irrigation application rates were obtained from Johnson's (1974) crop budget work reported in Appendix E. These are also shown in Table 2.7. It was not possible within the time frame and scope of the study to obtain more up-to-date application rates.

The marginal income per acre of irrigated land was calculated by taking 95 percent of the crop price multiplied by the crop yield per acre given in Table 2.7. The 95 percent figure was obtained from Johnson's work (Appendix E) and allows for a 5 percent charge for the management and marketing services of the farm operators. This marginal income per acre (column (5) Table 2.7) was then divided by the gross irrigation application to determine a water value in $/ac-ft/yr. As can be seen from Table 2.7, this value varies from $2.90 for barley to $11.50 for hay and up to $178.50 for potatoes. As discussed above, potatoes do not reflect the value of water for a marginal increase in water supply and were, therefore, not included in the evaluation of the weighted mean water value of $7.10/ac-ft/yr. The weights used in calculating this mean were the total San Luis crop values as shown in column (9) of Table 2.7.

2.7.4 Information From Water Managers

Discussions were held with a selection of various senior people in federal, state, and local governmental agencies to obtain information on water values and also the potential market for additional water. The agencies contacted included:

- San Luis Valley Farmers Ranch Management Association;
- State Engineer's Office of New Mexico;
- Water Resource Department of the City of Albuquerque;

- Metropolitan Water Board of Santa Fe;
- Planning Group, USBR, Amarillo, Texas;
- Middle Rio Grande Conservancy District, Albuquerque, New Mexico; and
- El Paso, Texas Water Utilities Public Service Board.

The most reliable information obtained is summarized below:

Agricultural Water Use = $8-$30/ac-ft. $8/ac-ft is a rough estimate of current agricultural water value in the Albuquerque area. The $30 figure corresponds to the delivery price of water used for irrigation in the Rio Grande project area.

Municipal and Industrial = $30-$40/ac-ft. The $40 figure is what the city of Albuquerque is currently paying for San Juan-Chama project water. The $30 figure corresponds to the purchase price of water delivered to the city of El Paso, Texas from the Rio Grande Project.

The Middle Rio Grande Conservancy District (MRGCD) annually uses up to 20,000 ac-ft of San Juan-Chama water for irrigation. The value of the San Juan-Chama waters used for irrigation in the MRGCD has an estimated value of $6.25 in the El Vado reservoir and $40 to $60 by the time it is delivered to irrigation areas (B. Grano, USBR, personal communication).

2.7.5 Water Market

As part of the above mentioned discussions, inquiries were made on the status of the water market including future demands in various areas. The findings were as follows:

2.7.5.1 Colorado San Luis Valley

Present and future water demand is mainly in the agricultural sector (see Section 2.3.1).

2.7.5.2 New Mexico

Existing demand for Rio Grande water is entirely agricultural, although some municipalities would like to use it in the future. Albuquerque will use up to 48,200 ac-ft/year of San Juan-Chama water by the year 2028, but would still purchase new water for future use, if available (J. Gill, personal communication).

Recent studies by McDonald and Tysseling (1982), as well as Lansford, et. al. (1975) have attempted to identify future water use markets and demands. In the earlier study, surface water supply limitations were expected to impact employment, growth, and production values in the Middle Rio Grande region. A significant reduction in the agricultural sector was forecast as necessary in order for growth in other areas to occur (i.e. trade and services and manufacturing sectors, as well as associated population growth).

The more recent study reflects the impact of the San Juan-Chama Project upon water supplies in the Middle Rio Grande region. The future water demands were identified to be in the domestic, manufacturing, mining, power, and

military sectors. Agricultural water use was projected to experience zero growth between 1980 and 2000. A total projected increase in water use of 78,167 ac-ft by the year 2000 has been estimated by this study. This includes significant growth in domestic water demands in Benalillo County (including the city of Albuquerque). The study concludes that this projected increase in water by the year 2000 "can easily be accommodated by the new water supplies of 101,800 ac-ft available to the New Mexico Upper Rio Grande Basin from the San Juan-Chama Project during this time period". It also concluded that "water availability will not be a critical issue within the New Mexico Upper Rio Grande Basin over the next 20 years. This also implies that New Mexico will be able to stand by her water delivery commitment under the treaty with Mexico and the Rio Grande Compact".

The above study assumed that the current level of agricultural demand would not increase in the future. However, as discussed in Section 2.3.2 of this report, the gross water demand to supply all of the agricultural land exceeds the available supply by over 200,000 ac-ft/yr. Furthermore, for agricultural purposes, it is easier and cheaper to obtain additional water directly from the Rio Grande rather than from the San Juan-Chama Project. Because of stipulations attached to Chama water, it will be difficult to obtain future agricultural supplies from this source (Bob Grano, USBR, personal communication). It is, therefore, anticipated that there will be an agricultural market for marginal flows in the Rio Grande.

2.7.5.3 Texas

Agricultural water used from the Rio Grande Project is valued at $30/ac-ft/yr delivered (B. Cortez, personal

communication). The small amount of municipal water used by El Paso is also valued at $30/ac-ft/yr. The city of El Paso is actively involved in the purchase or lease of all available surface rights associated with the Rio Grande Project in order to secure future water supplies and extend the life of aquifer systems which currently supply the majority of the city's water needs.

Studies recently completed by the USGS indicate that current depletion rates (including consideration of growth in the El Paso area) will result in saline encroachment and contamination of current groundwater supplies by the year 2010 to 2015. Other studies for the City of El Paso have determined the following growth projections:

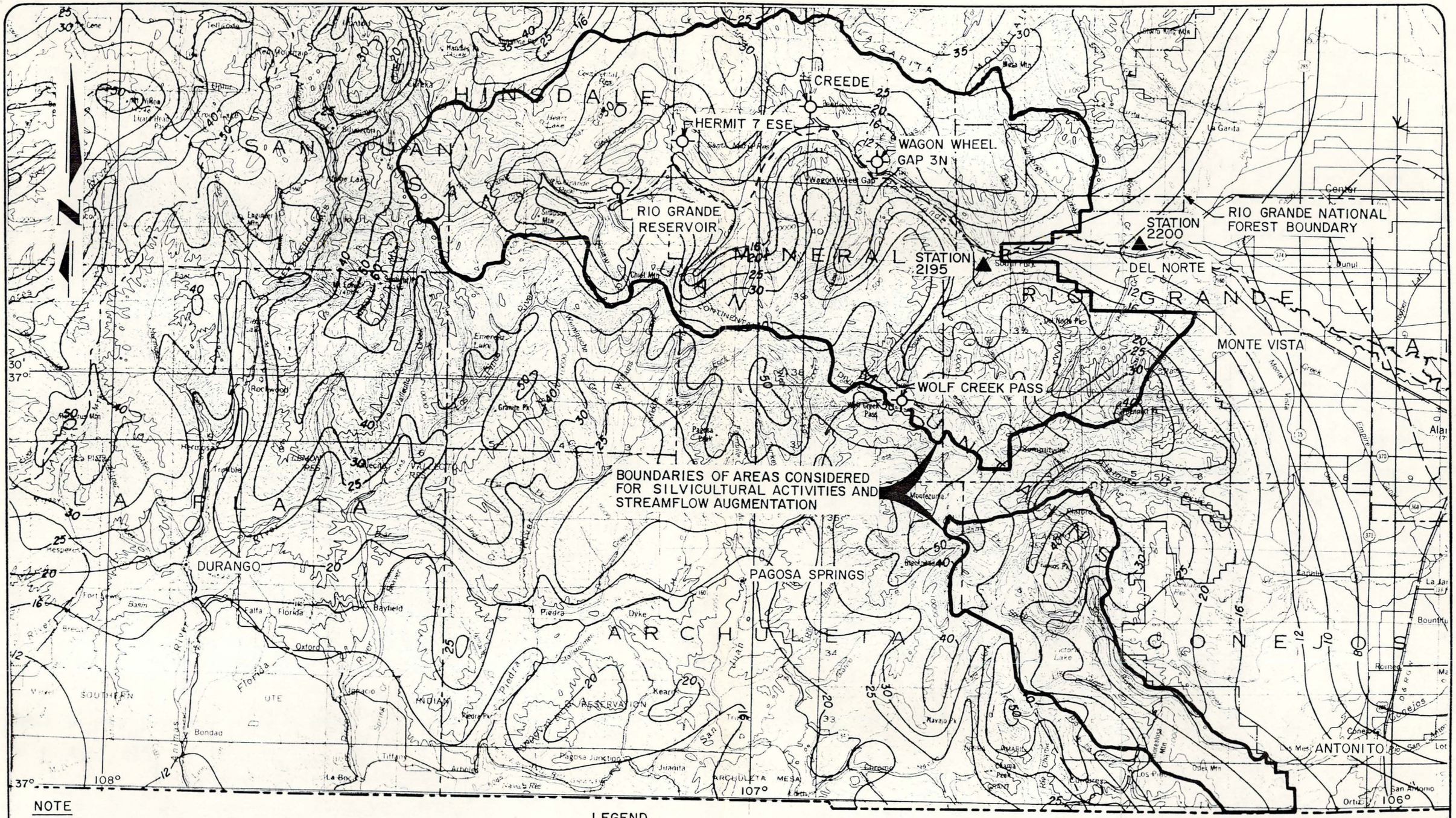
	Population
Current	475,000
Dec 1989	513,676
1999	613,316
2009	757,445
2019	901,575

El Paso currently supplies domestic water to total population of 495,000 which includes 20,000 outside of the city limits. This value of 495,000 was used as the base for calculating future water requirements as discussed below.

The estimated per capita water consumption is 185 GPD. By the year 1989, El Paso will need an additional 8000 ac-ft/yr to meet growing demands. Similarly, by 1999, the city will need an additional 28,700 ac-ft of supply (over 1985 quantities) to meet the needs of the projected population. Under current administrative

policies, this will require the purchase of water shares from 4000 (1989) and 14,350 (1999) agricultural acres of the Rio Grande Project (dependable yield of 2 ac-ft/yr). The preceding information was provided by Mr. John T. Hickerson (El Paso Water Utilities Public Service Board, personal communication).

The overall water market including future demands is a continuing picture of demands exceeding supply. The information suggests that alternate supplies will be required or administrative practices will need modification in order for production values and municipal growth to reach their potential. Incremental flow volumes as discussed in Section 2.5 that are allocated according to the Compact would not significantly affect the overall current and future demands of this region. It is anticipated that all incremental flows could be beneficially used without significant loss to Mexico.



NOTE

NORMAL ANNUAL PRECIPITATION ISOCHRONES TAKEN FROM U.S. DEPT. OF COMMERCE, ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION WEATHER BUREAU MAP, NORMAL ANNUAL PRECIPITATION 1931-1960, MAP COMPILED EDITED AND PUBLISHED BY THE U.S. GEOLOGICAL SURVEY.

LEGEND

- PRECIPITATION MEASUREMENT STATION
- 30 — NORMAL ANNUAL PRECIPITATION ISOCHRONE
- ▲ STREAM FLOW GAGING STATION

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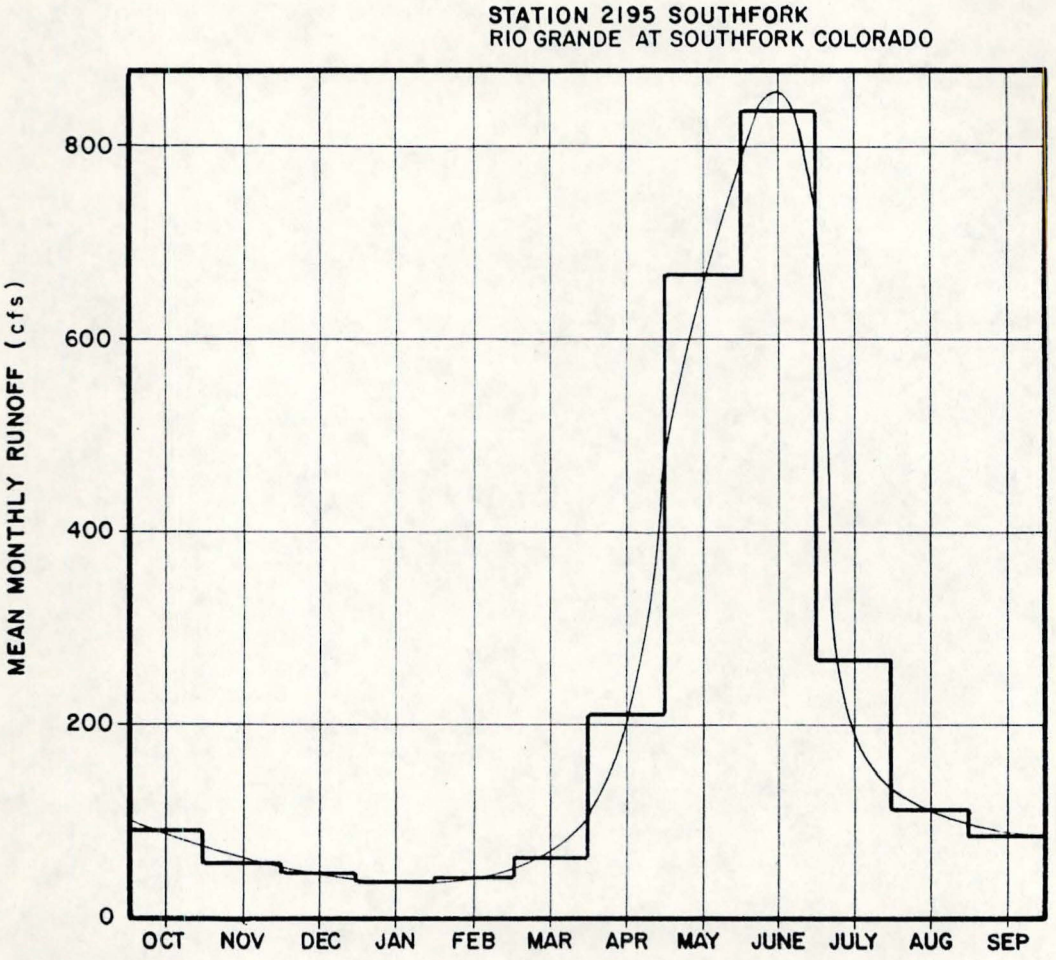
DATE 10/84	Consulting Engineers
REVISION NO. 0	

FIGURE 2.1

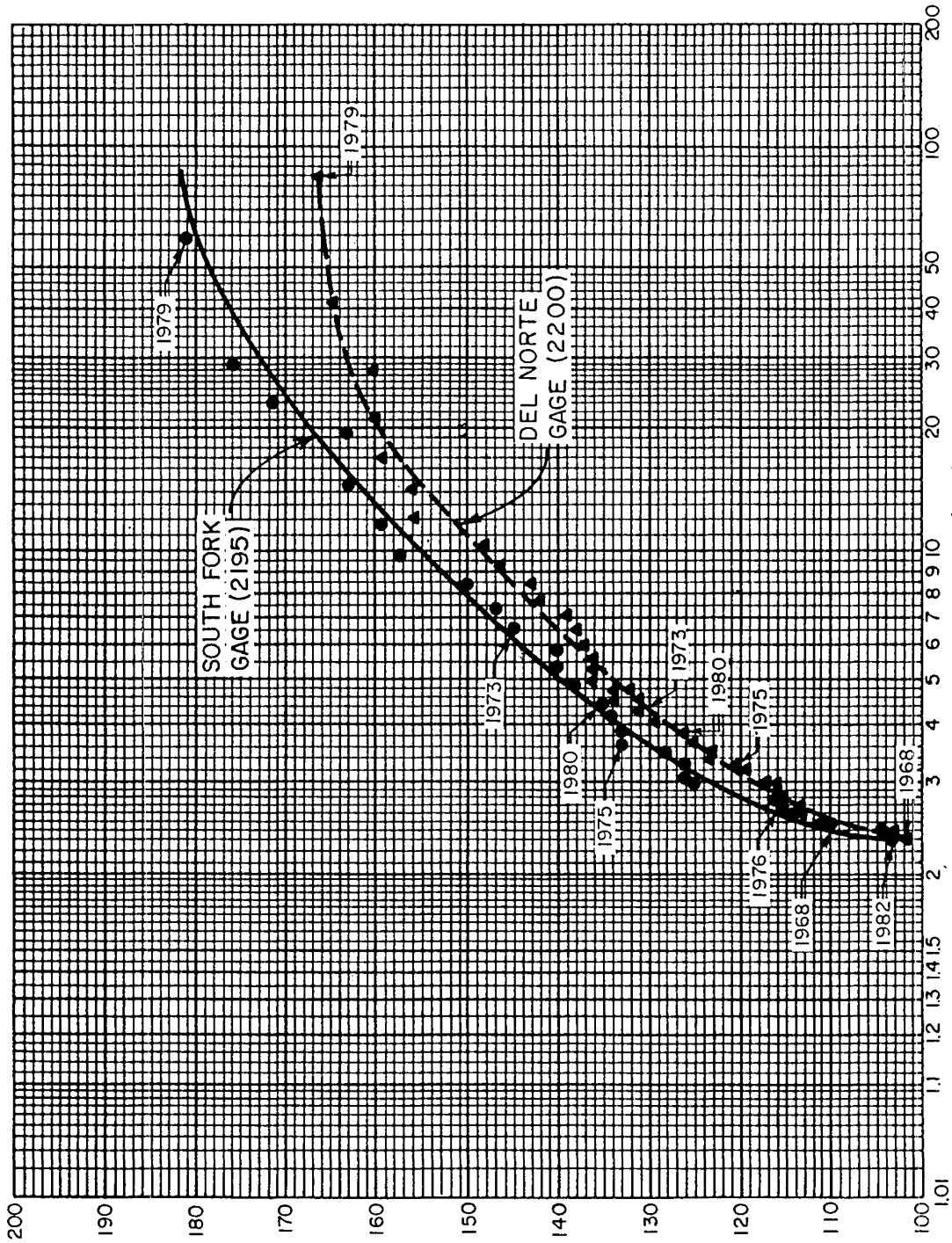
NORMAL ANNUAL PRECIPITATION ISOCHRONES IN THE UPPER RIO GRANDE BASIN



NOTE

MONTHLY DATA FROM 72 YR. DATA BASE OBTAINED FROM USGS "WATSTORE" COMPUTER FILES

PROJECT NO. 05601	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 2.2
DATE 10/84		AVERAGE ANNUAL RUNOFF HYDROGRAPH FOR STATION 2195
REVISION NO. 0		



NOTE; GAGING STATION LOCATIONS SHOWN ON FIG. 2.1

PROJECT NO. 05601	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 2.3 FREQUENCY PLOTS OF WET RUNOFF EVENTS
DATE 10/84		
REVISION NO. 0		

NOTE; GAGING STATION LOCATIONS SHOWN ON FIG. 2.1

PROJECT NO. 05601

DATE 10/84

REVISION NO. 0

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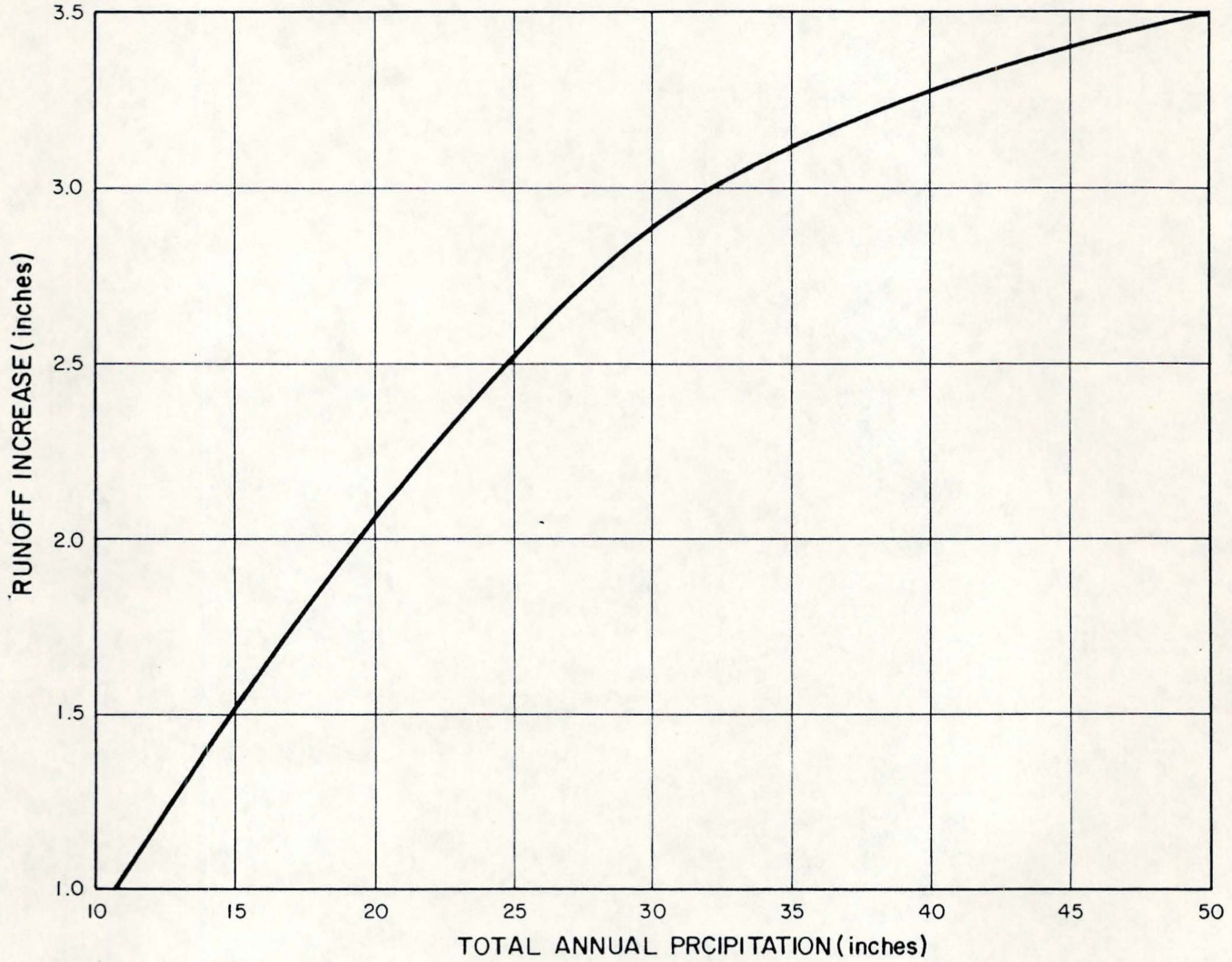
STEFFEN ROBERTSON & KIRSTEN

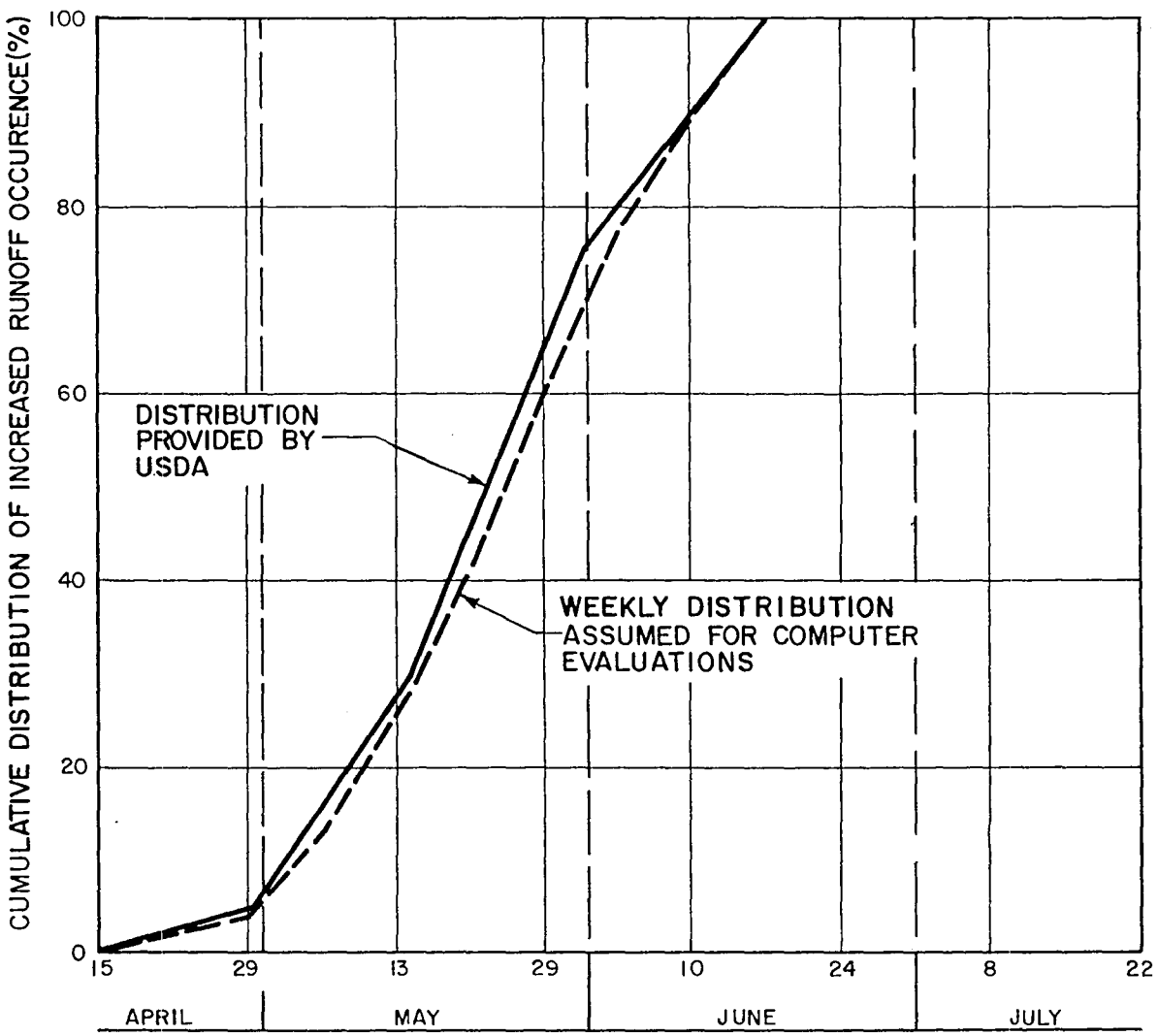
Consulting Engineers

FIGURE 2.4

FREQUENCY PLOTS OF DRY RUNOFF EVENTS

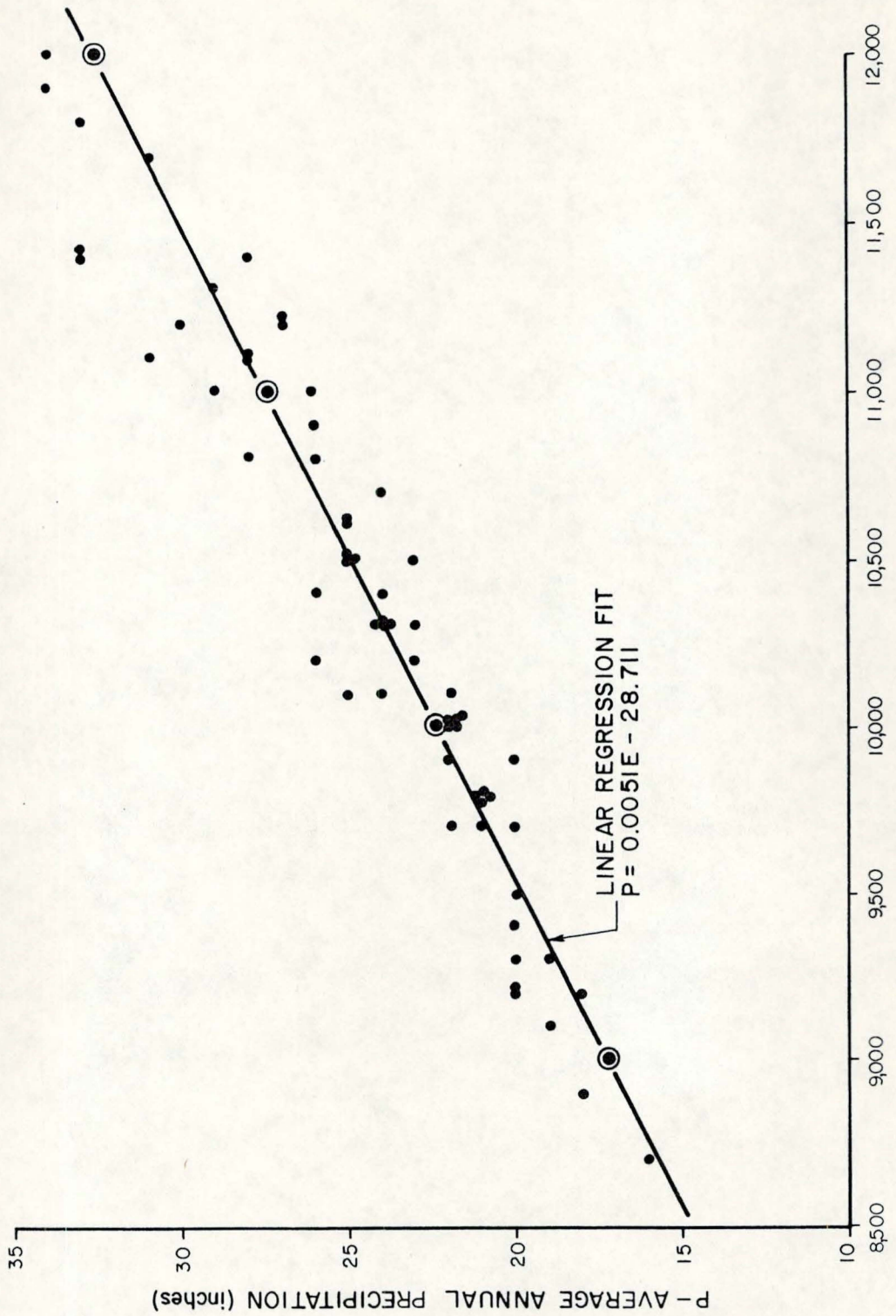


PROJECT NO. 05601	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 2.5
DATE 10/84		RUNOFF INCREASE vs. TOTAL ANNUAL PRECIPITATION IN THE UPPER RIO GRANDE BASIN
REVISION NO. 0		



PROJECT NO. 05601	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN	FIGURE 2.6
DATE 10/84	Consulting Engineers	CUMULATIVE DISTRIBUTION OF INCREASED RUNOFF OCCURRENCE
REVISION NO. 0		

PROJECT NO.
05601
DATE
10/84
REVISION NO.
0
PREPARED BY:
STEFFEN ROBERTSON & KIRSTEN
Consulting Engineers
FIGURE 2.7
PRECIPITATION DATA AT HERMIT 7 ESE STATION (1968-1982)
P_H = RECORDED ANNUAL PRECIPITATION (inches) AT HERMIT 7 ESE STATION
RECORDED ANNUAL PRECIPITATION (inches)
MEAN ANNUAL = 15.6 in.
STANDARD DEVIATION = 2.8 in.
20
18
16
14
12
10
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
WATER YEAR
ANNUAL PRECIPITATION AT OTHER BASINS (P_B) DETERMINED FROM THE FOLLOWING RELATIONSHIP: $P_B = 0.0051 (E_B - E_H) + P_H$ WHERE, E_B & E_H = ELEV. OF BASIN AND HERMIT 7 ESE STATION RESPECTIVELY (ELEV. 9,000 ft.)



PROJECT NO. 05601	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 2.8
DATE 10/84		SUMMARY OF PRECIPITATION vs. ELEVATION DATA FOR THE UPPER RIO GRANDE BASIN
REVISION NO. 0		

3.0 RIO GRANDE SYSTEM MODELING

This section of the report discusses the overall study methodology, including the computer program MODSIM/RIM selected and modified specifically for these studies. The discussion includes a description of the configuration of the computer model, and how the water allocation priority system is incorporated in the model. The computer model configuration and priorities were developed to simulate the physical river basin (shown on Figure 3.1) under the administration of the Rio Grande Compact and the legal and institutional setting of the states of Colorado, New Mexico, and Texas, as described in Section 2.0.

3.1 Description of Computer Program MODSIM

3.1.1 Basic Model Structure

The program MODSIM is a river basin simulation model that analyzes the transfer and storage of water within a multireservoir or multibasin system (Labadie, et. al., 1984). It has been developed primarily as an aid in river basin water management on a weekly or monthly basis. Though primarily a simulation model, MODSIM incorporates an efficient network optimization capability which allows systematic allocation of water according to user input priorities, water rights, and economic values. Since the network optimization is performed on a period by period basis, the model does not require accurate forecasts for implementation of the model results.

MODSIM uses network flow linear programming based on the out-of-kilter method (Ford and Fulkerson, 1962), which was designed for the solution of minimum "cost" flow network problems. For this case, the "costs" are not monetary but are dimensionless weighting factors which function to rank water supply allocations according to

user-supplied priorities. This algorithm allows for the efficient solution of relatively large and complex network systems. The efficiency of the algorithm stems mostly from the predominantly integer rather than real number calculations.

In MODSIM, a water system is defined by a series of nodes and links as shown in the insert to Figure 3.1 for this study area. Nodes are used to represent specific points of demand, inflow, or storage; the links between the nodes are used to represent actual river reaches, canals, or pipelines conveying water. Each water use or demand modeled by the nodes and links is assigned a priority number that is translated by the model into a "cost". The characteristics of the nodes and links are such that channel losses, losses due to evaporation, and irrigation return flows can be incorporated. In addition, a demand node can be specified as a flow-through demand in which the specified flow accrues to the next downstream node and thus stays within the system. This feature is particularly valuable for prioritizing instream water uses. All other consumptive demands are considered terminal and are removed from the system. However, the model is capable of computing return flows to a stream from agricultural and other uses. Inter-basin transfers are incorporated via import nodes which simply act as inflow nodes. Data entry is relatively simple and changes to an existing network can be achieved with minimal effort.

The modifications made to MODSIM for the purposes of this study deal with the assignment of actual water rights as demands. In addition, in order to model the existing Colorado legal system, a system of changing demands that could account for fluctuations of river flow was required. The range of possible water rights to be

evaluated is so great that inclusion of all of them into the permanent network would not be practically feasible. Alternatively, a method to select a desirable subrange of rights that would be sufficient to utilize all of the incremental flow for any given period was desired. Consideration of the dynamic nature of this subrange as a result of fluctuating river flows represents a major contribution to river basin modeling "state-of-the-art."

3.1.2 Inclusion of a Data-Base Management System

In order to perform the water right/demand selections for the State of Colorado, a data base management system called RIM (relational information management), was added to MODSIM. RIM is a code developed by the Boeing Company. It was selected primarily because it can be inserted as a callable subroutine in a Fortran program. The computer model is subsequently referred to as MODSIM/RIM.

The water rights listings from the office of the State Engineer for the Rio Grande and Conejos Rivers (Appendix D) have been used to create the data base. The selection of specific water rights to receive augmentation water from these prioritized lists are made on the basis of historical streamflows. The data base management system is used to identify the "swing ditch" on either the Conejos or Rio Grande Rivers based upon the historical base streamflow. The swing ditch is that marginal water right which does not receive water from the historical streamflow but which could be the first to receive any augmented supply. Once the swing ditch water right in the priority list has been identified, the allocation of augmentation streamflows can be accomplished in priority in a similar fashion, as is actually done in the field by the respective river commissioners.

The system of canals along both the Conejos and Rio Grande mainstem rivers in the San Luis Valley of Colorado serve specific regions as outlined on Figure 3.1. Because of the large number of water rights associated with the individual canals, the water rights listings are aggregated to represent regional distribution points which correspond directly to the turn out gates of all canals along the river. The model is, therefore, simplified to a system of permanent links and nodes representing the major regions of the San Luis Valley as shown on Figure 3.1. It should be emphasized, however, that all current water rights are included in the data base. The data base manager RIM was then used to select the swing ditch water rights and determine the regions associated with each right as variable demands. These variable demands are selected on a weekly basis and supplied into the pre-specified permanent network of links and nodes. This concept is illustrated in Figure 3.2 (details of model configuration are discussed in Section 3.2.).

By using the above procedure, the number of variable demand nodes in each region varies from period to period depending upon the current location in the water rights listing. The total number of variable demand nodes is specified by the user along with the rest of the input data for a particular model run. This total is further divided into the respective number of demands to be selected from each separate river basin (Conejos and Rio Grande).

A refinement of this procedure was made in order to further facilitate efficient computer usage and reduce output. For the purposes of this study, the particular region to which a water right is associated is sufficient information to determine its intended use. There is no

practical need to know anything more specific about the individual water rights. For this reason, the data base manager RIM takes strings of water rights located within the same region and groups them together to be treated as one large water right. This makes it much easier and more efficient to evaluate the system but does not alter the accuracy of the results.

As an illustration of this, part of the Rio Grande data base from Appendix D has been reproduced in Table 3.1. Referring to this table, note that the first four water rights listed above the indicated base flow are all in Region 4. If the hydrology indicated Sequence #22, Silva D., as the first water right to be supplied to the model as a variable demand for augmentation water, the data base manager would combine Sequence #'s 22 through 25 and supply this as variable demand D1 of 15.04 cfs attached to the permanent Region 4 node.

The data base manager RIM continues this process until it has identified the specified total number of variable demand nodes. Note that for water rights that do not occur in strings (as in Sequence #26, Atkins D.), the group cumulative demand is simply equal to the amount of the single water right. Ten variable demand nodes shown in Table 3.1 are illustrated schematically on Figure 3.2. As discussed earlier, RIM allows completion of this task for both the Conejos and Rio Grande Rivers for each time increment of the overall modeling time frame.

3.2 Network Configuration

3.2.1 Definition of Important Nodes

The model configuration representing the river system in Colorado, New Mexico, and Texas has been set up

TABLE 3.1

SUMMARY OF RIM VARIABLE DEMAND NODE SELECTION PROCESS

RIO GRANDE DATA BASE

SEQ #	Name	Appro Date	AMT (cfs)	CUM (cfs)	Region	Assigned Variable Demand Nodes
1	Silva D	3/12/1866	3.00	3.00	4	
2	Atencio D	4/15/1866	.74	3.74	4	
3	San Jose D	4/30/1866	.90	4.64	4	
4	Silva D	5/31/1870	11.00	15.64	4	
5	R G D #1	8/1/1870	12.80	28.44	4	
6	McDonald D	5/1/1872	12.80	41.84	1	
7	Prairie D	5/1/1872	3.00	44.84	2	
8	Coch/Pion	6/9/1872	2.50	47.34	1	
9	R G D #4	6/9/1872	1.20	48.54	4	
10	Horn/Ydren	4/15/1873	2.20	50.74	4	
11	Dyer D	4/30/1873	1.00	51.74	4	
12	McDonald D	5/31/1873	1.00	52.74	1	
13	Pace D	5/31/1873	1.40	54.14	4	
14	Loma D	1/1/1874	2.00	56.14	1	
15	Butler Irr	3/27/1874	1.00	57.14	2	
16	Butler Irr	3/27/1874	1.00	58.14	2	
17	Hubbard D	3/27/1874	1.00	59.14	2	
18	Centennial	4/20/1874	47.40	106.54	4	
19	Billings D	4/30/1874	1.50	108.04	2	
20	Fish D	4/30/1874	1.50	109.54	2	
21	Kane Ca'N	5/1/1874	1.60	111.14	1	Base Flow = 112 cfs
22	Silva D	5/12/1874	2.80	113.94	4	Swing ditch
23	Atencio D	5/31/1874	4.94	118.88	4	D1
24	Horn/Ydren	5/31/1874	4.40	123.28	4	
25	Anderson D	6/15/1874	2.90	126.18	4	
26	ATkins D	6/15/1874	.30	126.48	1	D2
27	Meadow Ofl	9/20/1874	3.20	129.68	4	D3
28	L, D, & B D	12/3/1874	1.80	131.48	4	
29	Anna Raber	3/31/1875	1.40	132.88	1	D4
30	Raber D	3/31/1875	1.40	134.28	1	
31	Excelsior	4/1/1875	8.40	142.68	3	D5
32	Kane Cal'N	5/1/1875	2.00	144.68	1	D6
33	Off D	5/1/1875	5.00	149.68	1	
34	McIntosh	5/3/1875	2.80	152.48	4	D7
35	R D G #2	5/3/1875	1.00	153.48	1	D8
36	Anderson D	5/31/1875	11.33	164.81	4	D9
37	Atkins D	5/31/1875	.67	165.48	1	D10
38	Kane Cal'N	6/7/1875	1.40	166.88	1	

as shown in Figure 3.1. This network consists of seven agricultural demand nodes, three Compact administration demand nodes, five reservoirs and six points of runoff inflow. The runoff inflow points represent the collective sub-basins as summarized in Table 2.4.

The agricultural demand nodes are made up of the five regions in Colorado (illustrated on Figure 3.1), the Middle Rio Grande Conservancy District and the Rio Grande Project in New Mexico and Texas. The five regions in Colorado represent areas that are served by a major canal system or systems. These regional areas are those for which the data base management system (RIM) has been incorporated into MODSIM. Demands from the water rights data base in Colorado are selected and assigned to their respective regional nodes on a weekly basis as outlined in Section 3.1. The demands for regions one through four are selected from the water rights listing for the Rio Grande mainstem and those for region five come from the Conejos River water rights listing (See Appendix D).

The Middle Rio Grande Conservancy District demand node collectively represents all of the users for that area of New Mexico. As was mentioned earlier, water for these users is completely administered by the District and it would, therefore, be impractical to break it down into individual water rights. Similarly, the node for the Rio Grande Project represents all of the demands for that respective area which is situated partly in New Mexico and partly in Texas.

Both of these demand nodes are treated as standard terminal demands by MODSIM. No modifications are made to them as is the case for the data base dependent variable demand nodes of regions 1 through 5 in Colorado. The

values for these demands are considered known and fixed and are entered into the model along with the other input data.

The inflow nodes in the network are at the Rio Grande, Continental, Santa Maria, and Platoro reservoirs and at the Del Norte and Mogote streamflow gaging stations. These nodes represent the respective hydrologic regions for which the increased runoff has been calculated. The values for these inflows are entered into the model on a weekly basis.

Reservoirs have been included into the model configuration but serve only an illustrative purpose at this stage. It was originally thought that they would play an important role in the study by providing the alternative of storing the increased streamflow in order that it be released at a later time in the irrigation season when water is in short supply. However, once the final increased runoff data were obtained, it was observed that the majority of this runoff occurs at points below the reservoirs, as shown on Figure 2.9. Therefore, this runoff is effectively unregulated. With this in mind, all the reservoir nodes have been set up with no storage capacity such that they act merely to allow water to flow through them down to the next downstream node.

3.2.2 Consideration of the Rio Grande Compact

The Compact demand nodes are set up to accurately depict the delivery requirements as set forth in the Rio Grande Compact and consist of the Lasauses node, Stateline node, and the Elephant Butte Supply node. All of these have been designated as flow-through demand nodes in which the desired flow stays within the system and can be utilized downstream.

The two-river administration of the Compact that exists in Colorado is denoted by the separate demand node on the Conejos at Lasauses just upstream of the Conejos/Rio Grande confluence. The amount of increased streamflow required at this point has been directly calculated from the Compact tables given in Appendix A. The actual volume calculations are described in Section 2.3.5. The Compact requirement for the Rio Grande mainstem has been determined in the same manner from its respective delivery table. The sum of these two delivery schedules constitutes the total demand placed at the state line demand node.

In a similar fashion, the flow-through demand required at Elephant Butte Supply has been determined from its respective Compact table. This water could actually either be stored in Elephant Butte Reservoir or be allowed to flow on to the Rio Grande Project. In either case, water is ultimately used by the project. No attempt was made at trying to store this water and later use it in a more optimally controlled fashion because there was not enough information available with which to derive operating criteria. For the purposes of this study, it is assumed that the water allocated to the Rio Grande Project by the model is stored and used at will by the constituents of the project.

The calculated demands for all three of the Compact nodes are assumed known and fixed (for each particular treatment level and time increment as discussed in Section 2.5), as with the agricultural demands for New Mexico and Texas. These values are likewise provided to the model as input data.

The final node in the model configuration is referred to as a zero capacity "dummy" storage node. It

does not represent a physical element of the system but is included strictly for aid in the modeling process. MODSIM regards reservoir "spills" as the highest cost (least desirable) flow in a network, and attempts to minimize outflows from the network. The use of this node provided the means to have Compact delivery water used first at the Rio Grande Project with excess water above the project demand being stored in Elephant Butte Reservoir as illustrated by the dashed line in Figure 3.1. Only when the capacity of Elephant Butte is exceeded will any flow occur to the zero capacity storage node representing overflow to Mexico and non-beneficial water use.

Regions 3 and 4 are the only two nodes that are being treated for return flows. Regions 1 and 2 are within the Closed Basin and no physical return flows occur. A detailed assessment of actual return flows is beyond the scope of this study. The estimated return flows from Regions 3 and 4 were based on data obtained from the Division Engineer in these regions and were taken at face value. As is indicated in the figure, the return from Region 3 flows to Region 4, and the return from Region 4 flows to the Rio Grande/Conejos confluence. The model handles return flows by utilizing user supplied criteria which calculates a percentage of the terminal demand from the specified node and accrues it to the respective return node. The use of lag times is possible but has not been included in this application due to the lack of reliable data for the river basin.

In the configuration shown in Figure 3.1, the Compact delivery demands have been depicted as separate links in order to aid in the illustration of the modeling process. In actuality, these links are not part of the

network. More accurately, flow into a downstream node must first travel through upstream nodes and links before reaching the respective downstream node. For example, flow going from Mogote to Lasauses would first go from Mogote to Region 5 and would then flow through a link connecting the Region 5 node with the Lasauses node.

3.2.3 Allocation Priority System

As was discussed earlier in Section 3.1, program MODSIM uses a system of priority numbers for carryover storage in each reservoir and satisfaction of demand at each demand node. Finding a minimum "cost" solution for allocation of water over a specified time increment means making sure that water is allocated in strict accordance with these priorities. The priority numbers function as weighting factors in order to rank water allocations. In this way, by properly choosing the priority numbers to be input into the model (for each modeled reservoir and demand location), it is easy to specify which demands will get water first, and likewise, those that will suffer cutbacks first. This method of prioritizing is very adaptable to reproducing the system of operations under decreed water rights as well as for projecting water allocation to agricultural, municipal and industrial users according to water values and highest anticipated benefits.

In MODSIM, the costs per unit of flow determined by the input priority numbers are calculated as follows:

$$C_i = (1000 - (DEMR_i \times 10)) \text{ or}$$
$$C_i = (1000 - (OPRR_i \times 10))$$

where:

i = demand node

C_i = negative "cost" of allocating one unit of water to demand or storage depending upon the nature of node i

$DEMR_i$ = user input priority number (between 1 and 99) for meeting demand at node i.

$OPRR_i$ = user input priority number (between 1 and 99) for meeting carryover storage targets at node i

There is a C_i associated with each reservoir and demand node. Note that this is a negative number and that the most negative C_i relative to all other C_i's will have the highest priority. That is, a negative cost actually represents a benefit. Therefore, a lower value of DEMR or OPRR will indicate a higher priority. This does not guarantee that the demand at a node with a high priority will always be met but that if shortages are to occur, they will affect demands with lower priorities first (see Labadie, et. al, 1984 for more details).

With this in mind, the Compact demands, which under the stipulation of 1968 must be satisfied fully each and every year, are given the highest allocation ranking by assigning priority numbers of the lowest magnitude. The numbering used for this particular network starts at a value of two and progresses in increments of two. The demand at the state line is given the highest ranking with a priority number of two. The Lasauses demand node follows with a priority number of four and the Elephant Butte Supply node is assigned a number of six.

The regional demands in Colorado change with each weekly period and, therefore, have different priority numbers for each period. The model was set up to automatically reassign these priorities each time new selections are made from the data base. This is done in a

strictly sequential fashion. Since the water rights themselves are set up in a successive sequential order, the priority number of each selected successive variable demand is increased by two. The first water right chosen is given a priority number of 8 which is directly above that for Elephant Butte Supply. The rest of the demands chosen in Colorado merely build upon this value. For the example given in Table 3.1 and shown on Figure 3.2, variable demand D1 would have a priority number of 8, D2 a priority number of 12, up to variable demand D10 with a priority number of 26.

The priority number assigned to the Middle Rio Grande Conservancy District follows directly after that of the last demand assigned in Colorado. This value in turn, is followed by the priority number for the Rio Grande Project which is the highest priority number of all the demands.

The overall operational results of the above priority assignments are as follows. The three Compact demands are satisfied first. The amount of available water above that required at the state line node remains in Colorado and is distributed in strict accordance with the doctrine of prior appropriation. The difference between the amount required at state line and that required at Elephant Butte Supply is allocated to the Middle Rio Grande Conservancy District. The Rio Grande Project then receives all of the flow-through demand that is required at Elephant Butte Supply.

3.2.4 Concept of Incremental Flow Modeling

The idea behind incremental flow modeling is to examine just a portion of the total flow in a river system. This concept is founded in the assumption that

the flow that is not studied does not have a significant effect on the flow that is. This is a new approach to river basin modeling which could possibly be applicable to many other cases. That is, most river basin management problems build on an inplace system where it is desired to determine the impact of additional inflows, additional demands, or additional storage. In many cases, it is not necessary to model the entire flow regime if the primary concern is the incremental effect of the strategies.

The modeling treatment used on the Rio Grande encompasses only those amounts of water which constitute the streamflow created by increased runoff. These flows amount to only a small percentage of the annual flow that occurs in the river basin. They have been assumed to occur directly on top of the historical hydrograph for each year that has been modeled. As an illustration of this, Figure 3.3 is a partial plot of the hydrograph from 1968 along with the streamflow contributed by increased runoff on the Rio Grande mainstem. This graph encompasses the entire frame for which the increased runoff is projected to occur.

One can see from this plot that the increased streamflow is indeed a small increment when compared with the total flow. Since the primary purpose of this study is to focus on the effects of this incremental amount of water in the system, modeling of total flow is not necessary. Dealing with a smaller data base by just modeling the augmented or the incremented flow is clearly advantageous.

In adopting the incremented flow modeling approach, it is assumed that all base conditions (such as Compact delivery requirements on the base flows) and demands have

been satisfied. In Colorado, the demands are based on water rights which are conditioned on the amount of flow in the river at any given time. Actual hydrographs from the Rio Grande mainstem and the Conejos River are used to determine at which point the base conditions occur. All of the water rights which are below this point are assumed to have been met fully. The water rights to serve as demands for the incremental flow are selected above the base conditions as is discussed in Sections 3.1 and 3.2.

Note that if the incremental flow approach had not been used, the same water rights would still be allocated the increased amounts of streamflow. However, before analyzing these water right demands, the model would have to first complete the process of allocating all of the base flow water to its respective rights. The incremental approach eliminates the process of distributing water that is known to be available and proceeds directly with allocating water that is available through silvicultural activity.

The treatment of incremental flow in New Mexico and Texas is a much simpler matter. The specific distribution of base flow for these areas is not known and cannot be accounted for due to central administration by the two previously mentioned controlling agencies. Therefore, incremental flow can be allocated to these two collective-user nodes without having to know the conditions reflecting base flow usage. Actually, if the full-scale flow were to be modeled, the task of separating the amount of increased flow allocated from that allocated by base flow could prove difficult.

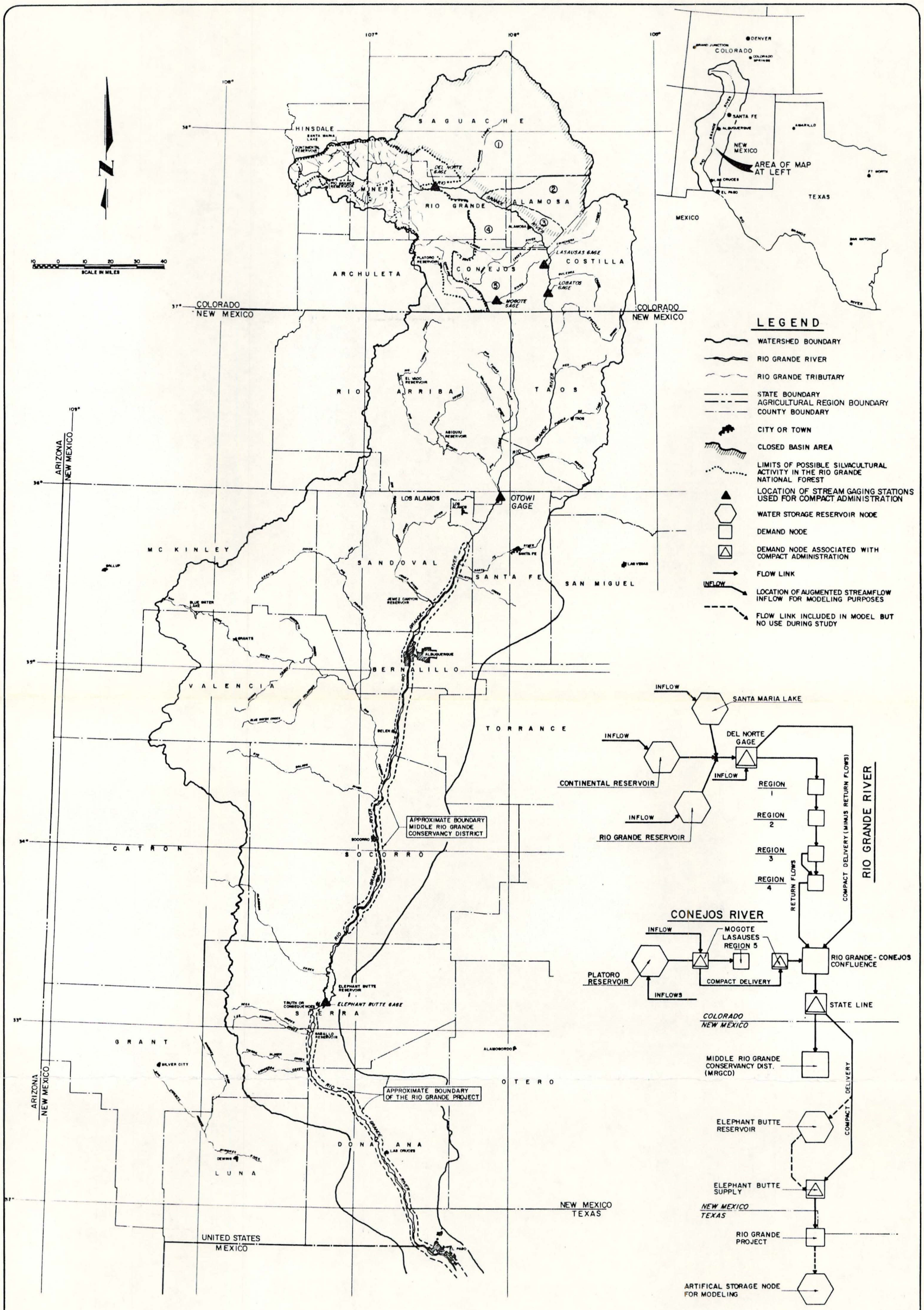
Another assumption that has been included in this approach concerns the losses associated with conveyance

but evaporation is considered in Elephant Butte

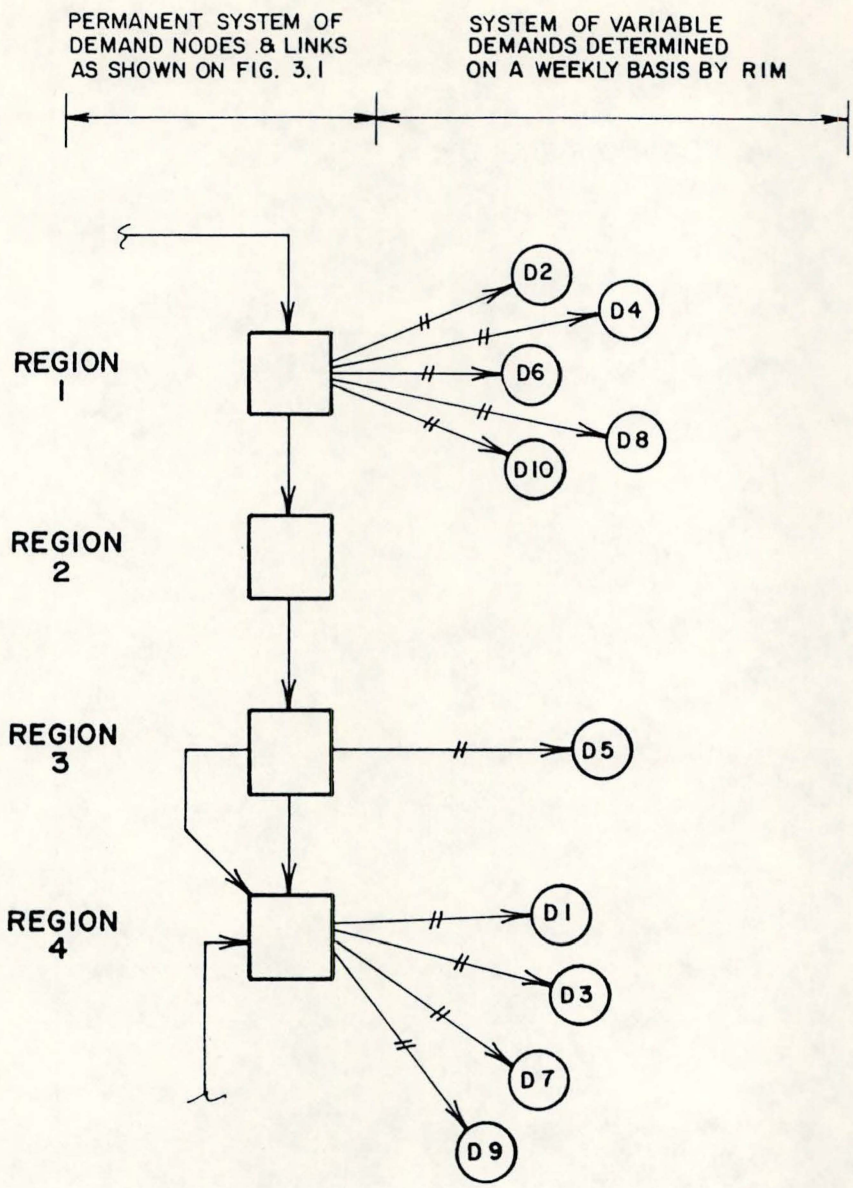
through a channel. Most natural channels lose a portion of their flow through seepage into the underlying strata. Although these losses can sometimes be quite substantial, they have been assumed to be small for the incremental flow and, therefore, negligible.

The advantages of incremental flow modeling are many. As previously mentioned, the fact that treatment of base flow conditions have been left out constitutes a savings in time (in terms of data collection and network set up). In addition, the system of water rights in Colorado is extensive, and many simplifications would be necessary in order to keep the size of the modeling network within manageable dimensions. This can result in less accurate results. Not only is the input data simplified under incremental flow analysis, but the output is in turn reduced. Only output pertinent to the study at hand need be analyzed.

Another point to be considered concerns the efficient use of computer time. The addition of the RIM routines for demand selection serves to increase the complexity of the MODSIM program structure. The implication of this is increased time required by the central processing unit. Therefore, any procedure to increase computer efficiency is highly desirable. As one would imagine, operating MODSIM and RIM under a scheme of incremental flow modeling requires only a fraction of the computer time that would be necessary to depict the entire flow.



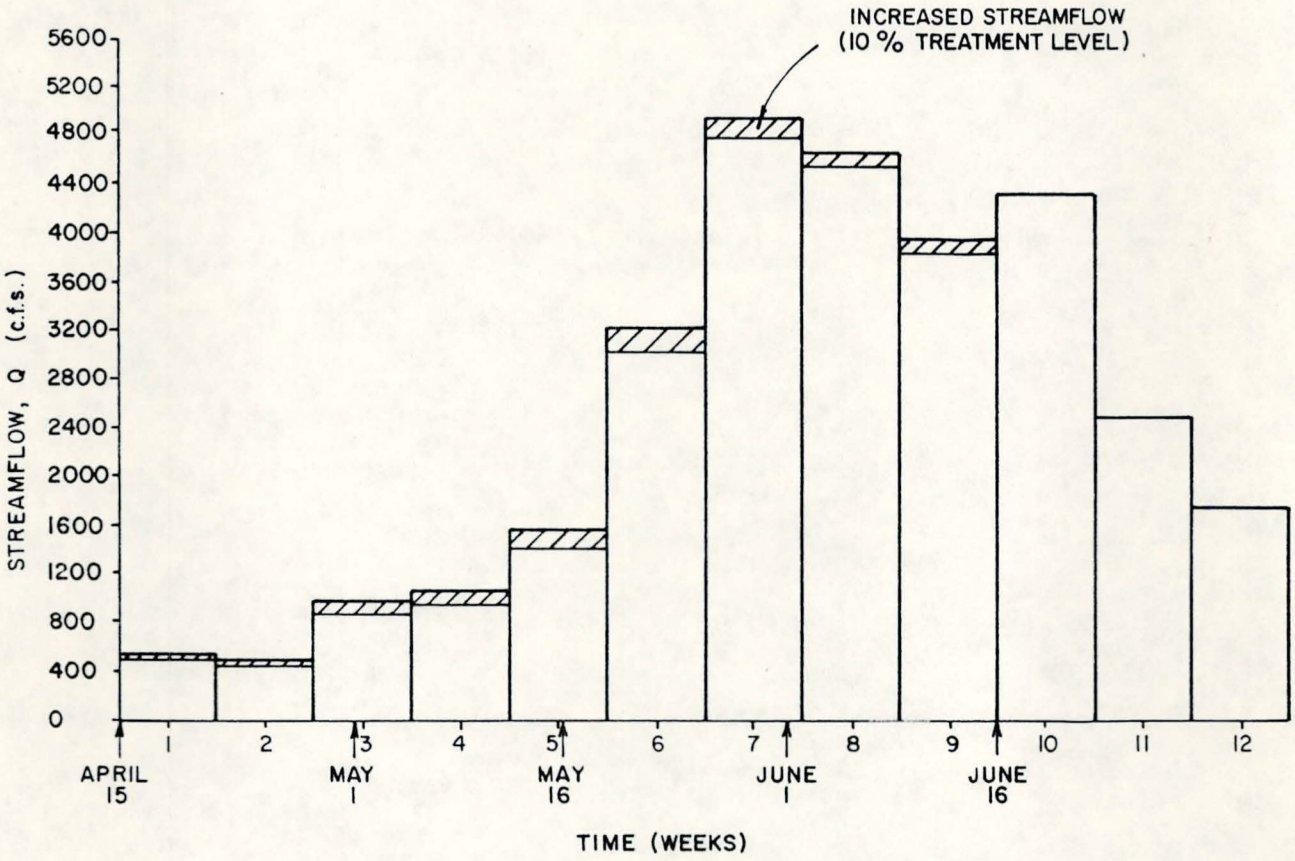
PROJECT NO. 5601	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 3.1 RIO GRANDE RIVER BASIN AND MODEL SCHEMATIC
FUNCTION NO.		
REVISION NO. A		



LEGEND

- PERMANENT DEMAND NODE
- PERMANENT FLOW LINE
- D1 — VARIABLE DEMAND NODE
- VARIABLE DEMAND NODE LINK

PROJECT NO. 05601	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 3.2
DATE 10/84		CONCEPT OF PERMANENT & VARIABLE DEMAND NODES USED TO MODEL WATER RIGHTS IN COLORADO
REVISION NO. 0		



PROJECT NO. 05601	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 3.3 PARTIAL HYDROGRAPH @ DEL NORTE GAGE (RIO GRANDE RIVER) INCLUDING INCREASED STREAMFLOW, 1968
DATE 10/84		
REVISION NO. 0		

4.0 STUDY CASES

4.1 General

Study cases were selected to determine the range of anticipated benefits under the current water distribution legal and institutional framework, as well as potential "future conditions". Because of the complexity of water administration in the river basin as the result of the Rio Grande Compact, the 1968 Compact stipulation, and the distinctly different water management objectives of the states of Colorado, New Mexico, and Texas, future conditions were selected to represent a wide range of potential benefits. Potential future conditions represented by the various study cases have differing probabilities of occurrence during the time period of 1985 to 1995. The discussion that follows deals with each of the different future scenarios. Section 5.0 discusses the benefits resulting from each of these. No attempt is made to account for the probability and risk factors that are necessary for an overall benefit/cost assessment which incorporates the full range of future conditions.

The following four study cases were identified and evaluated:

Study Case No.	Description
1	Current Institutional Framework
	1a. Without Closed Basin project water
	1b. With Closed Basin project water
2	Highest Benefit Allocation with Compact in place
3	Relaxation of 1968 Stipulation Requirements
4	Compact and State Administrative Constraints Removed

The results of these study cases can also be used to estimate the costs of the various state administrative, as well as Compact constraints in the Rio Grande system. The costs of the various

state administrative policies should be the difference between study cases 1 and 2. Similarly, the results of study cases 2 and 4 can be used to determine the cost of Compact constraints.

4.2 Current Institutional Framework - Study Case 1

This alternative represents baseline conditions incorporating the effects of the Rio Grande Compact, as well as State water laws and administrative practices. Under these conditions, it is assumed that water will be allocated in accordance with existing water rights and normal operating priorities. There may or may not be a perception on the part of these water users as to any increase in water supply.

The United States Department of the Interior, Bureau of Reclamation is currently involved in the development of the San Luis Valley Closed Basin Project. The overall objective of this project is the development of a network of shallow wells in the unconfined aquifer in the Closed Basin of Colorado. These wells will be used to salvage groundwater accumulating within the basin due to irrigation activities and to return it to the Rio Grande River. The project waters will be returning water to the Rio Grande mainstem below the locations of the major diversion headgates. For this reason, Closed Basin Project water will not be a direct supply for irrigation in Colorado. The project waters will be used primarily to help meet Compact delivery obligations of the State of Colorado. The net effect of the project will be greater flexibility in the administrative measures used by the Water Division No. 3 Engineer to meet Colorado's annual Compact delivery obligations and a reduction in previously curtailed water rights to meet these obligations. A small percentage of the water will be delivered to the National Wildlife Refuge in Colorado. The volumes of salvaged water anticipated annually from this project are as follows:

Stage	Annual Amount of Salvaged Water (ac-ft)	Published Delivery Date
1-2	13,347	October, 1985
3	42,500	October, 1986
4 (estimated)	31,500	October, 1987
5 (estimated)	14,000	October, 1988
Total	101,347	

Water from the project will be used for Compact delivery and at the National Wildlife Refuge according to the following schedule:

Amount	Use	Comment
1st 60,000 ac-ft	Compact delivery	All of stages 1,2 and 3
Next 12,500 ac-ft	National Wildlife Refuge	40% of Stage 4
All remaining	Compact delivery	Stage 4 and 5

In order to evaluate all potential conditions affecting water allocation under this study case, the following separate computer simulations were completed:

a. Water allocation for 10, 50, and 100 percent treatment levels without consideration of Closed Basin Project water, and

b. Water allocation for 10 percent treatment level including consideration of Closed Basin Project water.

With regard to Item b, a computer simulation was completed for the 10 percent treatment level only, (including Closed Basin Project water) to provide the basis for evaluations of all treatment levels.

The operation of the Closed Basin Project has some restrictions with regard to disturbing the groundwater boundary between the Closed Basin and Rio Grande Basin. The effect of large extraction volumes upon the boundary is currently unknown. Because of this uncertainty and the possibility of implementation delays, it is believed that Stages 1, 2, and 3 have the greatest potential for implementation during the 1985-95 period. With respect to disturbing the groundwater boundary, it should be noted that there are stipulations that this boundary will not be drawn down by more than 2 ft (San Luis Valley Project - Colorado Closed Basin Division; Facts and Concepts).

The Closed Basin Project waters will benefit the State of Colorado in two ways. First, it will allow increased delivery of otherwise curtailed water rights as a result of Compact delivery obligations. Second, Closed Basin water pumped into the lower reach of the river in Colorado that is in excess of Compact delivery requirements will serve as a credit to the accumulated debt of the State of Colorado. These two factors provide a unique set of considerations when trying to assess the impact that the Closed Basin Project will have upon the net benefit of incremental waters. These considerations are best illustrated by example. Table 4.1 is a reproduction of a portion of the information presented in Appendix B. This table shows the historical flows at the Del Norte gage and historical scheduled Compact deliveries at the Colorado state line (from Compact Commission Reports) along with the incremental flow volumes, new Compact delivery requirements for the total streamflows (including the incremental values), and the incremental flow Compact delivery requirements.

The historical Compact deliveries range from a minimum of 61,500 ac-ft in 1977 to a maximum of 383,700 ac-ft in 1979. As mentioned earlier, the Closed Basin waters will allow for increased delivery of the previously curtailed water rights in Colorado. Stages 1, 2, and 3 of the Closed Basin Project have an estimated

TABLE 4.1

COMPACT DELIVERY REQUIREMENTS OF THE RIO GRANDE RIVER MAINSTEM

	Compact Deliveries				Rio Grande Mainstem (Colorado)					
		Increased Streamflow Level of Treatment (%)				New Scheduled Delivery Level of Treatment (%)			Incremental Increase Compact Delivery Level of Treatment (%)	
Year	Historical Flow Rio Grande Index Supply*	100	50	10	Historical Scheduled Delivery*	100	50	10	100	50	10
1968	667.00	134.94	67.47	13.49	190.40	259.76	222.24	196.30	69.36	31.84	5.90
1969	657.60	140.02	70.01	14.00	185.30	255.67	217.94	191.50	70.37	32.64	6.20
1970	654.70	140.54	70.27	14.05	184.10	254.33	216.49	190.25	70.23	32.39	6.15
1971	484.40	121.72	60.86	12.17	122.30	164.45	142.39	125.97	42.15	20.09	3.67
1972	477.30	119.93	59.97	11.99	120.20	161.00	139.57	123.79	40.80	19.37	3.59
1973	832.20	140.54	70.27	14.05	279.50	402.74	337.22	289.38	123.24	57.72	9.88
1974	337.50	102.26	51.13	10.23	83.20	109.13	95.27	85.50	25.93	12.07	2.30
1975	807.10	144.20	72.10	14.42	262.00	381.30	317.11	272.06	119.30	55.11	10.06
1976	589.90	118.97	59.49	11.90	158.40	208.44	181.76	162.72	50.04	23.26	4.32
1977	215.30	111.52	55.76	11.15	61.50	80.86	69.21	62.65	19.36	7.71	1.15
1978	406.10	118.12	59.06	11.81	99.70	135.23	116.55	103.01	35.53	16.85	3.31
1979	953.70	145.99	72.99	14.60	383.70	539.66	459.36	398.30	155.96	75.66	14.60
1980	750.10	126.61	63.31	12.66	229.10	314.97	266.39	236.15	85.87	37.29	7.05
1981	409.30	126.61	63.31	12.66	100.60	139.21	118.78	104.15	38.61	18.18	3.55
1982	697.50	139.06	69.53	13.91	202.90	282.59	238.54	209.71	79.69	35.64	6.81

All quantities in thousands of ac-ft.

*From Rio Grande Compact Commission Reports.

average annual capacity of 55,850 ac-ft. This capacity is below the minimum historical scheduled Compact delivery of 61,500 ac-ft. This indicates that even in the driest years, Stages 1, 2, and 3 of the Closed Basin Project could not meet all of the Compact's requirements (on base flows only) and that consequently, curtailment of base flow irrigation diversions would still be required. Implementation of Stages 4 and 5 of the Closed Basin Project will be required before base flow Compact curtailments can be eliminated during the dry to average years.

This unique combination of Compact delivery requirements on base flows, as well as Closed Basin Project capacity, therefore, requires the adoption of a distribution strategy that does not bias the net benefit calculations. The adopted strategy is necessary for the interpretation of modeling results only. The strategy does not necessarily represent an actual physical occurrence.

There are three strategies to evaluate the effect of Closed Basin water on the net benefit of the incremental streamflows. These are:

1. Closed Basin waters can be considered to apply first to replace base streamflow Compact delivery requirements (Strategy 1).

2. Closed Basin waters can be considered in the same proportion (i.e. applied on a direct percentage basis) to Compact delivery requirements of both the base flows and incremental streamflow volumes (Strategy 2).

3. Closed Basin waters can be considered to apply first to incremental flow Compact delivery requirements, and second to base flow requirements (Strategy 3).

As previously discussed, the capacity of Stages 1, 2, and 3 of the Closed Basin Project never exceed the total Compact delivery

requirement associated with the base streamflows. Therefore, Strategy 1 would show no net impact on the allocation of incremental streamflows from the results for Study Case 1a. The Closed Basin Project would serve to fulfill a portion of the base flow Compact requirements allowing for increased allocation of base flows in Colorado. The net Compact requirement associated with incremental flows would remain the same and no net change in incremental water allocation in Colorado would occur.

Strategy 2 would show an approximate one percent increase in the amount of water delivered to Colorado (10 percent treatment level) with a corresponding (less than one percent) decrease in the water allocation to the States of New Mexico and Texas. For all practical purposes, the effect of Closed Basin water allocated according to Strategy 2 (for the 10 percent treatment level) is negligible to the overall net benefit calculations. The effects of Strategy 2 to the 50- and 100-percent treatment levels are estimated to be 15 and 28 percent, respectively.

The impact of the Closed Basin Project (Stages 1 and 2, or 1, 2, and 3) according to Strategy 3 will be significant. An average annual increase of 5,900 ac-ft allocation of incremental waters in Colorado will result for the 10 percent treatment level. This is without consideration of increased return flows from Regions 3 and 4 in the lower basin area. For the 10 percent treatment level, the results are independent of the implementation of Stage 3 of the Closed Basin Project. Average annual increased allocation in Colorado for the 50- and 100-percent treatment levels would be 31,000 and 55,850 ac-ft, respectively, with Stage 1 through 3 of the project in operation.

Study Case 1 represents the adminstrative framework with the highest probability of being enforced over the 1985 to 1995 time period of all the study cases selected for analysis. The computed program MODSIM/RIM, along with the network model described in Section 3.0, were used to simulate the impact of this study case.

4.3 Highest Benefit Allocation with Compact - Study Case 2

This alternative assumes that the marginal increase in streamflow can and will be allocated to specific water users. However, the interstate Compact is still assumed to be the primary allocation device between states. In other words, the Compact will allocate water to the three states, but economic decisions will allocate water within states. This study case considers the possibility of marginal flows to be used for the growing Municipal and Industrial (M&I) demand for water in both the States of New Mexico and Texas. No significant M&I demands are assumed for Colorado.

This type of water allocation could occur if the marginal increase in streamflow could be determined by a court ruling to be "special" and allocated within the Compact restrictions to the highest beneficial use. This study case represents a considerable effort on behalf of the USDA to obtain "special" designation of the water in water court. We believe that even this level of effort has only a low to moderate probability of success and implementation over the time period from 1985 to 1995.

No special model runs were completed to simulate these conditions. Evaluation of benefits was achieved by altering the value of water and using the water allocation volumes determined from Study Case 1.

4.4 Relaxation of the 1968 Compact Stipulation Requirements - Study Case 3

This alternative study case assumes that the marginal increase in streamflow is managed to the extent possible within the reservoir systems in the upper basin areas of Colorado. With relaxation of the 1968 stipulation, Colorado would be allowed to carry over Compact commitments from one year to the next and would,

therefore, likely assume water management policies that maximize the in-state allocation of marginal waters by storing water during high-flow periods, and releasing during low-flow periods to reduce annual fluctuations in water delivered for irrigation and to minimize over-delivery of Compact requirements.

The 1968 Compact stipulation will be relaxed if and when Elephant Butte Reservoir in New Mexico discharges water over its spillway, or when Colorado's total debt is repaid. This study case represents a combination of water administration policies in Colorado, and actual physical runoff from the upper river basin, that have a relatively low probability of occurring over the time period from 1985 to 1995. The most likely occurrence would be a spillway discharge at Elephant Butte reservoir.

In order to fully exploit the benefits of relaxation of the 1968 stipulations, Colorado would have to add additional storage facilities, or divert and store more Rio Grande water in the Closed Basin, or implement some combination of these two measures. The total economic impact of these measures would be a small shift in benefits from New Mexico and Texas to Colorado.

From a rational point of view, the benefit of this case study would not be significantly different from those of Study Case 1. Some reduction would be appropriate to account for the cost of the engineering measures in Colorado. Accurate determination of these benefits and costs are beyond the scope of this study. For planning and ranking purposes, it can be assumed that the benefits are the same as for Study Case 1.

removed for increased flows only.

4.5 Compact and State Administrative Constraints Removed - Study Case 4

This study case assumes that the marginal increase in streamflow could be allocated to the highest beneficial use in the entire river basin without regard to the Compact or any state,

legal, and institutional policies. This type of water allocation would only be possible if marginal streamflow increases were determined by court ruling as "special" (such as non-tributary or developed water) and if the Compact were nullified. We believe that this combination of factors has a very low probability of occurring over the 1985 to 1995 time period.

Benefits associated with this case were derived by assuming all marginal streamflow could be allocated according to current water demands (Section 2.3) and future water markets (Section 2.7.5) to the highest value use. No additional computer simulations were undertaken.

5.0 STUDY RESULTS

This section summarizes the results of the computer simulations described in Section 4.0, and presents benefit evaluations for each of the study cases. Allocation of increased streamflow to the various regions are combined with economic value of water to develop approximate financial benefits under the different scenarios considered.

5.1 Determination of Water Values

Most of the economic analyses performed in this section are expressed in terms of mean annual values. These are calculated first by averaging the annual quantities of water allocated by the computer model over the hydrologic simulation period and then multiplying these averages by the value of water.

The following economic analyses have also considered the losses and returns of incremental flows where they could be reliably determined or estimated. A summary of the losses and returns are as follows:

- Return flows from Region 4 of Colorado - 12 to 15 percent
- Transportation and other losses in the Middle Rio Grande Conservancy District - 70 percent
- Total (evaporation, seepage and transportation) losses from the Rio Grande Project - 57 percent
- Reservoir losses (evaporation and seepage) for hydropower estimations - 35 percent

Return flows from Region 4 were considered in all model runs using MODSIM/RIM. The losses from the MRGCD and Rio Grande Project have been considered in the water allocation and economic benefit summaries presented in the following sections.

The unit values of water used for economic evaluations are as follows:

Agricultural	
Colorado	$7/ac-ft/yr
New Mexico	$8/ac-ft/yr
Texas	$30/ac-ft/yr
M&I	
Colorado	No M&I use of incremental flows (both current and future)
New Mexico	No M&I use under current conditions. Future conditions = $40/ac-ft/yr.
Texas	$30/ac-ft/yr. ave = 122 KWH/ac-ft @ $.013/KWH

5.2 Current Institutional Framework - Study Case 1a

5.2.1 Water Allocation

Table 5.1A summarizes the gross average annual water allocation (for Study Case 1a) to the various states for the three levels of treatment. Detailed results are presented in Tables F-1 through F-3 in Appendix F. The results show that for the 50 percent level of treatment (i.e. 25 percent deforestation), the average annual increase in water supply is 75,100 ac-ft. Of this, 37,000 ac-ft or 49 percent would be retained by Colorado, 6,400 ac-ft (9 percent) would be retained in New Mexico and the remaining 31,700 ac-ft (42 percent) would pass on to Texas. As discussed in Section 2.0, this allocation is determined by the interstate Compact.

By using the loss factors discussed above, the average annual net water deliveries were evaluated and are listed in Table 5.1B. It is these net values that were used in the economic benefit evaluations discussed in the following sections.

TABLE 5.1A

SUMMARY OF AVERAGE ANNUAL GROSS WATER ALLOCATION - STUDY CASE 1a

(Ac-ft)

Level of Treatment	Colorado Agriculture	New Mexico Agriculture	Texas Agriculture/ Municipal	Total
10%	7,900	1,200	5,900	15,000
50%	37,000	6,400	31,700	75,100
100%	67,800	12,600	68,900	149,300

TABLE 5.1B

SUMMARY OF AVERAGE ANNUAL NET WATER DELIVERY AFTER LOSSES

STUDY CASE 1a

Level of Treatment	Colorado	New Mexico	Texas	
			Agriculture/ Municipal	Hydropower
10%	7,900	360	2,537	3,835
50%	37,000	1,920	13,631	20,605
100%	67,800	3,780	29,627	44,785

The average annual allocation of water within Colorado, which is governed by the current water rights, is shown in Table 5.2. For the 50 percent treatment case, region #1 receives 40 percent; region #2, 15 percent; region #3, 6 percent; region #4, 31 percent; region #5, 7 percent; and the Rio Grande Reservoir, 1 percent of Colorado's allocation.

TABLE 5.2

ALLOCATION OF ADDITIONAL WATER WITHIN COLORADO

STUDY CASE 1a

Level of Treatment	Percent Allocation to Region # 1	2	3	4	5	Percent to R.G. Reservoir
10%	41	16	4	31	7	1
50%	40	15	6	31	7	1
100%	42	16	5	28	7	2

The above values refer to average annual conditions. Figure 5.1 demonstrates how gross state allocations vary for different hydrologic conditions. The actual annual allocations derived from the computer model simulations are plotted on Figure 5.1 for the 50 percent level of treatment. Although there is scatter in the data, trend lines can be drawn through the points. The scatter in these data is caused by variations in return flow values each year. These variations, in turn, are a result of the different hydrograph shapes resulting in a varying allocation to the different regions which each have their own return flow components. These trends illustrate that Colorado receives most of the allocation during the dry years and decreasing amounts as the years become wetter. This is because the Compact requires an ever-increasing proportion of flow at the Del Norte and Mogote gages as annual flow volumes increase. As the values on Table 2.1 illustrate, a 600,000 ac-ft flow at Del Norte requires a delivery of 27 percent (161,000 ac-ft) to New Mexico. At 1,200,000 ac-ft, this percentage increases to 53 percent (i.e., 640,000 ac-ft).

Both Texas and New Mexico receive relatively small allocations during dry years. Allocation to the State of

New Mexico declines rapidly for slightly wetter than average years. This again, is because of the large percentage flows that must be delivered to Texas during high flow years (See Table 2.2). On the other hand, the allocation to Texas continuously increases as the years get wetter. For wetter than average years this allocation exceeds the amount due to Colorado.

5.2.2 Economic Benefit

As shown in Table 5.3, average annual benefit (1985 dollars) varies from $140,000 for the 10 percent level to $1,465,000 for the 100 percent treatment level. The values are based on the assumption that all the incremental water allocated to all three states is used for agricultural or municipal and electric generation purposes that are consistant with the current demand structure described in Section 2.3.

TABLE 5.3
SUMMARY OF ECONOMIC BENEFITS - STUDY CASE 1a

Level of Treatment	Average Annual Benefit $1000's			
	Colorado Agriculture	New Mexico Agriculture	Texas Agr-Mun/ Hydropower	Total
10%	55	3	76/6	140
50%	259	15	409/33	716
100%	475	30	889/71	1465

5.2.3 Colorado Water Rights Affected by Incremental Flows

A significant range of water rights on the Conejos River and Rio Grande River mainstem would be affected by incremental flows. The highest priority water rights are

affected at the lowest flows that generally occur during the early portion of the spring runoff hydrograph. Conversely, the lowest priority water rights are affected during the time when the maximum combination of base and incremental flow occur. This generally corresponds to the time when the baseflow hydrograph is at its peak.

In order to determine the range of water rights affected by incremental flows; base flows, compact curtailments on baseflows, estimated incremental flows, and estimated Compact curtailments of the incremental flows were evaluated. Base flows and incremental flow for the entire simulation period on the Rio Grande mainstem are summarized in Tables 5.4 and 5.5, respectively. Similarly, Conejos base flows and incremental flows are summarized in Tables 5.6 and 5.7, respectively. Compact curtailments on the minimum baseflows of the overall hydrograph can be estimated from the information summarized in Table 2.1. Estimated Compact curtailments of the incremental flows used as input data to Study Case 1a model studies are summarized in Table 5.8 (detailed information given in Appendix B).

Using this information, the range of affected sequence numbers (corresponding to water rights as shown in Appendix D) for typical dry, average, and wet years (1977, 1982, and 1979, respectively) of the simulation period were determined for each treatment level. These results are summarized in Table 5.9.

The following example illustrates the evaluations that were completed. The example is for water rights affected on the Rio Grande River mainstem during an average year (1982) for the 50 percent treatment level:

TABLE 5.4
RIO GRANDE MAINSTEM BASEFLOWS (AVERAGE-CFS) AT DEL NORTE GAGE*

		1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Week #1	April 15 - 22	512	566	295	966	871	416	275	323	457	575	379	987	579	520	799
Week #2	April 22 - 29	466	1279	488	565	1469	667	567	861	709	583	486	1801	1000	853	590
Week #3	April 29 - May 6	875	1710	669	656	2040	1262	900	868	1244	887	664	2219	1189	1721	1274
Week #4	May 6 - 13	934	1546	1969	794	1734	2099	1944	1167	1544	1388	542	2380	2007	1104	1513
Week #5	May 13 - 20	1406	2517	3814	1322	1953	3546	2227	3414	3004	667	1453	2293	1554	846	1144
Week #6	May 20 - 27	3021	4061	4103	1253	2551	4793	1770	4016	3529	464	1772	5199	3523	1397	1980
May #7	May 27 - June 3	4782	4127	3459	1994	3194	4027	2470	3791	3877	859	2120	6961	4616	2437	3400
Week #8	June 3 - 10	4553	3253	2444	2420	2920	4214	1750	5203	4540	1359	3154	6911	5913	2840	3383
Week #9	June 10 - 17	3857	2529	2183	3000	2257	5610	1521	5063	3287	605	3767	6500	5934	2373	3696
Week #10	June 17 - 24	4320	1690	2480	2967	1394	4260	1083	4117	2263	294	2716	5256	4359	897	3389
Week #11	June 24 - July 1	2519	1869	2239	2429	1002	4900	660	4253	1883	271	2093	4813	3679	645	3369
Week #12	July 1 - 8	1763	1823	1797	1740	690	3707	387	4204	1957	256	1151	3807	3016	497	2284

*As taken from Rio Grande Compact Commission Reports

TABLE 5.5

SUMMARY OF ESTIMATED INCREMENTAL FLOWS (CFS)

FOR THE RIO GRANDE MAINSTEM (AT DEL NORTE GAGE)*

10% TREATMENT LEVEL

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
April 13 - 30	21	22	22	19	19	22	19	23	19	18	19	23	20	20	22
May 1 - 15	113	118	118	102	101	118	86	121	100	94	99	123	106	106	117
May 16 - 31	191	199	199	173	170	199	145	205	169	158	168	208	180	180	197
June 1 - 15	113	118	118	102	101	118	86	121	100	94	99	123	106	106	117

50% TREATMENT LEVEL

April 15 - 30	107	111	111	96	95	111	96	114	94	88	93	115	100	100	110
May 1 - 15	567	589	591	512	504	591	430	606	500	469	497	614	532	532	584
May 16 - 31	957	993	997	863	851	997	725	1023	844	791	838	1036	898	898	986
June 1 - 15	567	589	591	512	504	591	430	606	500	469	497	614	532	532	584

100% TREATMENT LEVEL

April 15 - 30	213	221	221	192	189	221	192	227	187	176	186	230	199	199	219
May 1 - 15	1134	1177	1181	1023	1008	1181	859	1212	1000	937	993	1227	1064	1064	1168
May 16 - 31	1913	1985	1993	1726	1701	1993	1450	2045	1687	1581	1675	2071	1795	1795	1972
June 1 - 15	1134	1177	1181	1023	1008	1181	859	1212	1000	937	993	1227	1064	1064	1168

*DETAILED INFORMATION GIVEN IN APPENDIX B

TABLE 5.6

CONEJOS BASEFLOWS (AVERAGE CFS)

AT THE MOGOTE GAGE*

		1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Week #1	April 15 - 22	201	217	135	356	238	140	146	124	174	205	204	264	280	158	407
Week #2	April 22 - 29	165	474	191	233	402	253	331	364	321	220	299	759	928	319	271
Week #3	April 29 - May 6	370	784	234	318	559	449	474	331	596	453	303	817	916	764	929
Week #4	May 6 - 13	515	669	878	366	512	774	925	484	592	530	249	901	990	398	855
Week #5	May 13 - 20	564	1001	1597	402	626	1312	1224	1494	1260	252	805	1090	652	315	654
Week #6	May 20 - 27	1290	1749	1794	458	711	1651	1336	1453	1337	205	985	1876	1289	339	894
Week #7	May 27 - June 3	1783	1947	1436	928	716	1407	1264	1136	1556	382	1271	2010	1630	860	1773
Week #8	June 3 - 10	1693	1621	1011	985	608	1459	675	1879	1803	351	1447	2091	1823	1058	1674
Week #9	June 10 - 17	1431	1120	832	1024	480	1981	569	1713	1250	179	1800	1763	2016	795	1907
Week #10	June 17 - 24	1631	1114	1123	1108	287	1746	561	1553	824	93	1309	1773	1933	334	1876
Week #11	June 24 - July 1	895	865	91	745	160	1823	523	1503	580	73	940	2011	1643	224	1844
Week #12	July 1 - 8	467	857	539	547	115	1550	307	1466	434	57	548	1517	1201	169	1326

*AS TAKEN FROM RIO GRANDE COMPACT COMMISSION REPORTS

TABLE 5.7

SUMMARY OF ESTIMATED AVERAGE INCREMENTAL FLOWS (CFS)

FOR THE CONEJOS RIVER (AT MOGOTE GAGE)*

10% TREATMENT LEVEL

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
April 15 - 30	3	3	3	3	3	3	2	3	3	2	3	3	3	3	4
May 1 - 15	16	17	17	14	14	17	12	17	14	13	14	17	15	15	17
May 16 - 31	27	28	28	24	24	28	20	29	23	22	23	29	25	25	28
June 1 - 15	16	17	17	14	14	17	12	17	14	13	14	17	15	15	17

50% TREATMENT LEVEL

April 15 - 30	15	15	15	14	13	15	11	16	13	12	13	16	14	14	18
May 1 - 15	79	83	83	72	70	83	58	84	70	64	69	86	74	74	83
May 16 - 31	133	139	140	121	118	141	98	143	117	108	116	146	126	126	139
June 1 - 15	79	83	83	72	70	83	58	84	70	64	69	86	74	74	83

100% TREATMENT LEVEL

April 15 - 30	30	31	31	27	26	31	22	32	26	24	26	32	28	28	37
May 1 - 15	158	166	166	144	141	167	116	169	139	128	138	173	149	149	165
May 16 - 31	266	279	281	243	237	282	196	286	234	216	233	292	252	252	278
June 1 - 15	158	166	166	144	141	167	116	169	139	128	138	173	149	149	165

*DETAILED INFORMATION GIVEN IN APPENDIX B

TABLE 5.8

SUMMARY OF ESTIMATED CURTAILMENTS IN COLORADO

FOR TYPICAL DRY, AVERAGE, AND WET YEARS

	100% Treatment			50% Treatment			10% Treatment		
	Total Inc. Flow (x1000 ac-ft)	Compact Del (x1000 ac-ft)	% Curtail-ment	Total Inc. Flow (x1000 ac-ft)	Compact Del (x1000 ac-ft)	% Curtail-ment	Total Inc. Flow (x1000 ac-ft)	Compact Del (x1000 ac-ft)	% Curtail-ment
1977 Curtailments (Dry)									
Rio Grande	111.52	19.36	17	55.76	7.71	14	11.15	1.15	10
Conejos	15.26	4.66	31	7.63	1.61	21	1.53	0	0
1979 Curtailments (Wet)									
Rio Grande	145.99	155.96	100+	72.99	75.66	100+	14.60	14.60	100
Conejos	20.60	19.0	92	10.30	9.52	92	2.06	1.94	94
1982 Curtailments (Ave)									
Rio Grande	139.06	79.69	57	69.53	35.64	51	13.91	6.81	49
Conejos	19.63	18.06	92	9.81	9.03	92	1.96	1.80	92

TABLE 5.9

SEQ #'s AFFECTED BY INCREMENTAL FLOWS*

Level of Treatment	Dry Year 1977		Wet Year 1979		Average Year 1982	
	RG	C	RG	C	RG	C
10%	63-74	7-25	74-**	8-30	68-98	9-30
50%	63-82	7-26	74-**	8-30	68-117	9-30
100%	63-88	7-29	74-**	8-30	68-136	9-30

good!

* Sequence numbers shown on water rights listings in Appendix D
** Compact tables require average of 100 percent curtailment of incremental flows during peak runoff period.

RG = Rio Grande River mainstem
C = Conejos River

Highest Priority Water Right

Minimum Baseflow = 590 cfs (Table 5.4, week #2)
Compact Curtailment = 159 cfs (27 percent, Table 2.1)
Allocated Baseflow = 431 cfs

This corresponds to Sequence #68 (Loma D) shown in Appendix D. Incremental flows would affect water rights beginning at Sequence #68.

Lowest Priority Water Right

(a)	Maximum Baseflow	=	3,400 cfs (Table 5.4, week #7)
(b)	Compact Curtailment	=	2,040 cfs (60 percent, Table 2.1)
(c)	Allocated Baseflow	=	1,360 cfs
(d)	Incremental Flow	=	986 cfs (Table 5.5, May 16-31, 50 percent treatment)
(e)	Incremental Flow Curtailment	=	503 cfs (51 percent, Table 5.8)
	Maximum Allocated Flow (c+d-e)	=	1,843 cfs

This corresponds to Sequence #117 (Farmers Union) shown in Appendix D. Incremental flows affect water rights up to Sequence #117 during the maximum flow period.

In summary, the incremental flows would impact water rights between Sequence #68 and 117 on the Rio Grande mainstem during an average year such as 1982 (50 percent treatment level).

5.3 Current Institutional Framework Plus Allowance for Closed Basin Water Use in Colorado - Study Case 1b

5.3.1 Water Allocation

The effects of Closed Basin Project waters on the overall net benefit of incremental waters can be evaluated in three alternative ways as discussed in

Section 4.2. Because of the lower values of water (under "future conditions") in the State of Colorado, the most significant effect will be associated with Strategy 3 which provides for the greatest allocation of water in Colorado. Results based upon Strategy 3 represent the lower bound net benefits of the Study Case 1 conditions. The results which follow correspond to Strategy 3.

Table 5.10 summarizes the allocation to the various states for the 10-, 50-, and 100-percent levels of treatment with stages 1 and 2 of the Closed Basin Project in operation. The results for the 50- and 100-percent treatment levels have been interpreted from the MODSIM/RIM simulations of the 10-percent treatment level. As is to be expected, the results demonstrate that the additional water supply generated by the Closed Basin Project equivalent to the incremental increase in Compact delivery requirement is re-allocated within Colorado. The slight increase in total allocations over Study Case 1a is due to return flows from Regions 3 and 4 in Colorado. Table 5.11 summarizes how the additional water generated by the 10-percent treatment level would be distributed within Colorado.

TABLE 5.10A

SUMMARY OF AVERAGE ANNUAL GROSS WATER ALLOCATION - AC-FT

STUDY CASE 1b

Level of Treatment	Colorado	New Mexico	Texas	Total
10%	14,532	155	597	15,284
50%	51,300	4,237	20,985	76,522
100%	82,990	10,736	58,706	152,432

TABLE 5.10B

SUMMARY OF AVERAGE ANNUAL NET WATER ALLOCATION AFTER LOSSES

STUDY CASE 1b

Level of Treatment	Colorado	New Mexico	Texas	
			Agriculture/ Municipal	Hydropower
10%	14,532	47	257	388
50%	15,300	1,271	9,024	13,640
100%	82,990	3,221	25,244	38,159

TABLE 5.11

ALLOCATION OF ADDITIONAL WATER WITHIN COLORADO

10 PERCENT TREATMENT LEVEL - STUDY CASE 1b

% Allocation to Region #					% to R.G. Reservoir
1	2	3	4	5	
40	13	6	28	12	1

5.3.2 Economic Benefit

Table 5.12 is a summary of the average annual benefits for Study Case 1b. The average annual benefits vary from $111,000 for the 10 percent treatment to $1,425,000 for the 100 percent treatment level. As for Study Case 1a, these values are based on the assumption that all the incremental water allocated to all three states is used primarily for agricultural purposes.

TABLE 5.12

SUMMARY OF ECONOMIC BENEFITS - STUDY CASE 1b

Level of Treatment	Average Annual Benefit $1000's			
	Colorado	New Mexico	Texas Agr.-Mun. Hydropower	Total
10%	102	0	8/1	111
50%	359	10	270/22	661
100%	581	26	757/61	1425

Comparing these results with those presented in Table 5.3 indicates the type of shift in net benefits between the states that could be anticipated as a result of the Closed Basin Project using a modeling and data interpretation strategy like number 3 outlined in Section 4.2. As can be seen, the Closed Basin Project has the most significant effect upon the 10-perecent treatment level (21 percent decrease in average annual benefits over Study Case 1a). The effect of Stages 1 and 2 of the Closed Basin Project upon the 50- and 100-percent treatment levels would be 8 and 3 percent, respectively.

5.4 Highest Benefit Allocation With Compact - Study Case 2

For this case, the water volume allocations would be as for Study Case 1a. The impact of Closed Basin Project waters has been neglected (as per evaluation Strategy 1 described in Section 4.2.) The allocated water is assumed to have a value of $40/ac-ft in New Mexico. A value of $7/ac-ft is assumed for Colorado agricultural use. An increase of municipal water use in Texas can be assumed but water values of $30/ac-ft assumed for Study Case 1a would not change.

The results are summarized in Table 5.13.

TABLE 5.13

SUMMARY OF ECONOMIC BENEFITS - STUDY CASE 2

Level of Treatment	Average Annual Benefit - $1000's Colorado	New Mexico	Texas Agr./Mun. Hydropower	Total
10%	55	14	76/6	151
50%	259	77	409/33	778
100%	475	151	889/71	1586

5.5 Relaxation of 1968 Stipulation Requirements - Study Case 3

As discussed in Section 4.0, the benefits of this case are assumed to be similar for Study Case 1, with the exception of a higher proportion of water being allocated to Colorado. Total benefits for all three states would be similar to those given in Table 5.3.

5.6 Compact and State Administrative Constraints Removed - Study Case 4

With all constraints removed (i.e. Compact as well as the individual state administrative policies), one would expect the water to be ultimately allocated to the highest value, i.e. municipal and industrial use (M&I) of up to 78,200 ac-ft in New Mexico, and for agricultural and municipal use in Texas. Under these conditions, if Colorado does not have an adequate M&I demand, then the water would be acquired and used by New Mexico at a value of $40/ac-ft and by Texas at a value of $30/ac-ft. Transportation losses for municipal use in New Mexico would be minimal (10 percent). Average return flows on the order of 50 percent from New Mexico municipalities would be anticipated. Allocations considering no significant change in M&I demands in Colorado are shown in Table 5.14. Table 5.15 is a summary of anticipated economic benefits.

TABLE 5.14A

SUMMARY OF AVERAGE ANNUAL GROSS WATER ALLOCATION

STUDY CASE 4 (AC-FT)

Level of Treatment	Colorado	New Mexico	Texas	Total*
10%	-	15,000	-	14,645
50%	-	73,300	-	73,300
100%	-	78,200	68,170	146,370

*Note total values reflect decrease from Table 5.3 values due to loss of return flows from Colorado.

TABLE 5.14B

SUMMARY OF AVERAGE ANNUAL NET WATER ALLOCATION

WITH RETURN FLOWS AND LOSSES - STUDY CASE 4

(AC-FT)

Level of Treatment	New Mexico**	New Mexico*** Returns	Texas Agriculture/ Municipal	Texas Hydropower
10%	13,500	6,750	2,903	4,388
50%	65,970	32,985	14,184	21,440
100%	70,380	35,190	44,445	67,184

**Assumed conveyance losses of 10 percent.

***Assumed 50 percent return flows from municipal uses.

TABLE 5.15

SUMMARY OF ECONOMIC BENEFITS - STUDY CASE 4

	Average Annual Benefit - $1000's			
Level of Treatment	Colorado	New Mexico	Texas	Total*
10%	-	540	94	634
50%	-	2,639	460	3,099
100%	-	2,815	1,440	4,255

5.7 Summary of Results

a. Average Annual Benefits

Table 5.16 summarizes the total average annual benefits associated with the various study cases.

b. Present Value of 1985-1994 Benefits

In order to more realistically assess the total benefits, the present value of a stream of average annual benefits for the 10-year period 1985 through 1994 were evaluated. In calculating the present value, it was assumed that the average annual value of water would inflate by 5 percent and that the appropriate interest rate is 10 percent. The rest of the 10-year present value benefits are summarized in Table 5.17.

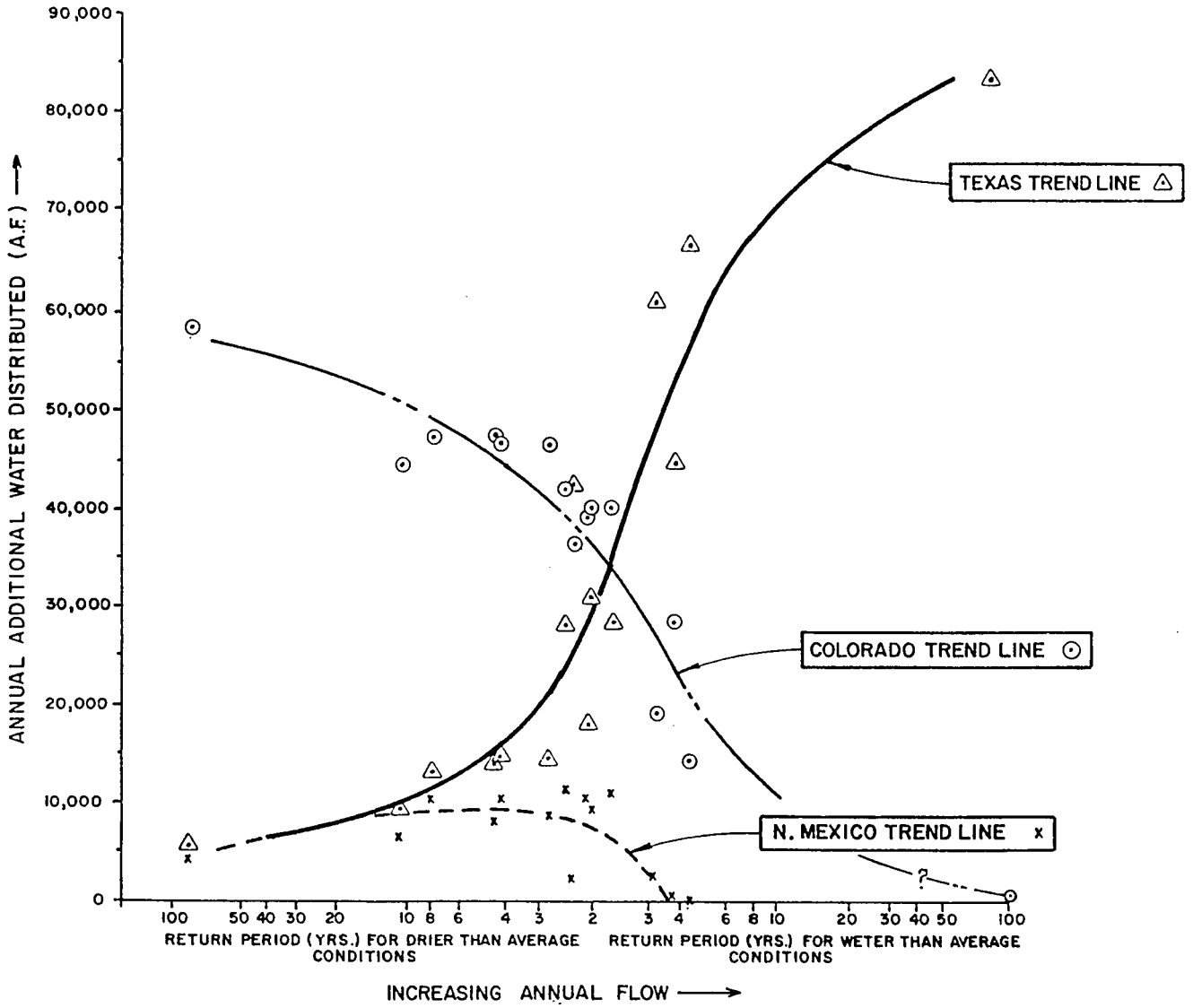
TABLE 5.16
SUMMARY OF AVERAGE ANNUAL ECONOMIC BENEFITS - $'s
All Study Cases

Level of Treatment	Study Case and Description			
	1-Current System	2-Compact with Highest Benefit Allocation	3-1968 Stipulation Removed	4-Highest Benefit Allocation
10%	140,000	151,000	140,000	634,000
50%	716,000	778,000	716,000	3,099,000
100%	1,465,000	1,586,000	1,465,000	4,255,000

TABLE 5.17

SUMMARY OF PRESENT VALUE OF BENEFITS - $'s

Level of Treatment	Study Case and Description			
	1-Current System	2-Compact with Highest Benefit Allocation	3-1968 Stipulation Removed	4-Highest Benefit Allocation
10%	1,121,400	1,209,510	1,121,400	5,078,340
50%	5,735,160	6,231,780	5,735,160	24,822,990
100%	11,734,650	12,703,860	11,734,650	34,082,550



NOTE

VALUES BASED ON STUDY CASE 1
AND 50 % TREATMENT LEVEL

PROJECT NO. 05601	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 5.1 ALLOCATION OF ADDITIONAL STREAMFLOW TO STATES UNDER VARYING HYDROLOGIC CONDITIONS
DATE 10/84		
REVISION NO. 0		

6.0 SUMMARY AND CONCLUSIONS

The study conclusions can be summarized as follows:

- An effective computer flow model capable of evaluating incremental flow quantities has been set up and used to determine how any additional water supplied to the Rio Grande system would be distributed. The computer program MODSIM has been expanded to include capabilities of data base management (MODSIM/RIM). With these modifications, the model can account for all of the individual water rights on both the Rio Grande mainstem and Conejos Rivers in Colorado to properly determine water allocation under this state's doctrine of appropriation. The model is capable of simulating distribution in Colorado on a much more detailed basis and is, therefore, ideally suited to more in-depth follow-up studies that may be required.

- For the four study cases selected for evaluation, the additional average annual quantities (gross) of water that would be generated for a 50-percent treatment level, and the distribution of this water to the various states is as follows:

Study Case	Colorado	New Mexico	Texas	Total
1a Current Situation	37,000	6,400	31,700	75,100
1b Current Situation with Closed Basin Water	51,300	4,237	20,985	76,522
2 Highest Benefit Allocation with Compact	37,000	6,400	31,700	75,100
4 Compact and State Admin. Constraints Removed	-	73,300	-	73,300

- Approximate values of water have been determined. These amount to $7 to $30/ac-ft/yr for agricultural water and $30 to $40/ac-ft/yr for municipal and industrial (M&I) use (1985 dollars). The agricultural value is conservatively based on

crops having low rates of return as it is those crops that would be brought into production with marginal increases in water supply. The M&I value is conservatively based on recent long-term bulk sales of water to the El Paso and Albuquerque municipality.

- It is beyond the scope of this study to deal with details such as differing seasonal water values, water values within various demand regions, and the time rate of growth of water demanded and value. The economic benefits calculated, therefore, are approximate and represent the potential that could be realized.

- For the four cases studies, the estimated mean annual and 1985 present worth benefits for the 50-percent treatment level are as follows:

Study Case	Mean Annual Benefit	Present Value Benefit
1 Current Situtation	716,000	5,735,160
2 Highest Benefit Allocation with Compact	778,000	6,231,780
3 1968 Stipulation Removed	716,000	5,735,160
4 Highest Benefit Allocation without Compact	3,099,000	24,822,990

The present worth benefit is based on the silvicultural activity being fully effective for the period, 1985 through 1995. It is assumed that water values escalate at an annual rate of 5 percent, and that the appropriate discount rate is 10 percent.

- For the four study cases, the estimated mean annual value of water leaving the Rio Grande National Forest for the 50-percent treatment level is as follows:

Study Case #	Mean Annual Value $/Ac-ft
1a	9.53
1b	8.64
2	10.36
3	9.53
4	42.28

7.0 RECOMMENDATIONS

This study has provided approximate economic benefits for a proposed range of silvicultural activities. These values are sufficiently accurate for planning and ranking purposes. However, should more detailed decision making be required such as sizing and designing an appropriate silvicultural activity and developing details of the associated river basin management practices to maximize the benefits of such activities, more comprehensive studies would be required. Such studies would generally focus on increasing the level of detail in the determination of water values and water allocation. Additional studies should include the following:

- Improved hydrologic modeling of the proposed silvicultural activity (including calibration of such a model);

- Development of more detailed information on the time distribution of the incremental water supplies;

- Assessment of water values on a regional basis and a projection of water demands in these regions with time. This would include an assessment of seasonal variation of water values and the rate of growth of these values;

- Quantification of competing water supply schemes, (e.g. the San Juan/Chama Scheme), and the incorporation of such schemes in the computer modeling; and

- Application of the model to study in more detail the use of incremental flow in various regions and to optimize management of this supply including consideration of reservoir strength.

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APPENDIX A
RIO GRANDE RIVER COMPACT
1968 COMPACT STIPULATION

ARTICLE 66

Rio Grande River Compact

37-66-101. Rio Grande River compact.-- The general assembly hereby approves the compact between the states of Colorado, New Mexico, and Texas, designated as the "Rio Grande compact", signed at the city of Santa Fe, state of New Mexico, on the 18th day of March, A.D. 1938, by M. C. Hinderlider, commissioner for the state of Colorado; Thomas M. McClure, commissioner for the state of New Mexico; Frank B. Clayton, commissioner for the state of Texas, and approved by S. O. Harper, representative of the President of the United States, which said compact is as follows:

RIO GRANDE COMPACT

The state of Colorado, the state of New Mexico, and the state of Texas, desiring to remove all causes of present and future controversy among these states and between citizens of one of these states and citizens of another state with respect to the use of the waters of the Rio Grande above Fort Quitman, Texas, and being moved by considerations of interstate comity, and for the purpose of effecting an equitable apportionment of such waters, have resolved to conclude a compact for the attainment of these purposes, and to that end, through their respective governors, have named as their respective commissioners:

For the state of Colorado--M. C. Hinderlider
For the state of New Mexico--Thomas M. McClure
For the state of Texas--Frank B. Clayton

who, after negotiations participated in by S. O. Harper, appointed by the President as the representative of the United States of America, have agreed upon the following articles, to-wit:

ARTICLE I

(a) The state of Colorado, the state of New Mexico, the state of Texas, and the United States of America, are hereinafter designated "Colorado," "New Mexico," "Texas," and the "United States," respectively.

(b) "The commission" means the agency created by this compact for the administration thereof.

(c) The term "Rio Grande basin" means all of the territory drained by the Rio Grande and its tributaries in Colorado, in New Mexico, and in Texas above Fort Quitman, including the closed basin in Colorado.

(d) The "closed basin" means that part of the Rio Grande basin in Colorado where the streams drain into the San Luis lakes and adjacent territory, and do not normally contribute to the flow of the Rio Grande.

(e) The term "tributary" means any stream which naturally contributes to the flow of the Rio Grande.

(f) "Transmountain diversion" is water imported into the drainage basin of the Rio Grande from any stream system outside of the Rio Grande basin, exclusive of the closed basin.

(g) "Annual debits" are the amounts by which actual deliveries in any calendar year fall below scheduled deliveries.

(h) "Annual credits" are the amounts by which actual deliveries in any calendar year exceed scheduled deliveries.

(i) "Accrued debits" are the amounts by which the sum of all annual debits exceeds the sum of all annual credits over any common period of time.

(j) "Accrued credits" are the amounts by which the sum of all annual credits exceeds the sum of all annual debits over any common period of time.

(k) "Project storage" is the combined capacity of Elephant Butte reservoir and all other reservoirs actually available for the storage of usable water below Elephant Butte and above the first diversion to lands of the Rio Grande project, but not more than a total of 2,638,860 acre-feet.

(l) "Usable water" is all water, exclusive of credit water, which is in project storage and which is available for release in accordance with irrigation demands, including deliveries to Mexico.

(m) "Credit water" is that amount of water in project storage which is equal to the accrued credit of Colorado, or New Mexico, or both.

(n) "Unfilled capacity" is the difference between the total physical capacity of project storage and the amount of usable water then in storage.

(o) "Actual release" is the amount of usable water released in any calendar year from the lowest reservoir comprising project storage.

(p) "Actual spill" is all water which is actually spilled from Elephant Butte reservoir, or is released therefrom for flood control, in excess of the current demand on project storage and which does not become usable water by storage in another reservoir; provided, that actual spill of usable water cannot occur until all credit water shall have been spilled.

(q) "Hypothetical spill" is the time in any year at which usable water would have spilled from project storage if 790,000 acre-feet had been released therefrom at rates proportional to the actual release in every year from the starting date to the end of the year in which hypothetical spill occurs, in computing hypothetical spill the initial condition shall be the amount of usable water in project storage at the beginning of the calendar year following the effective date of this compact, and thereafter the initial condition shall be the amount of usable water in project storage at the beginning of the calendar year following each actual spill.

ARTICLE II

The commission shall cause to be maintained and operated a stream gauging station equipped with an automatic water stage recorder at each of the following points, to-wit:

(a) On the Rio Grande near Del Norte above the principal points of diversion to the San Luis valley;

(b) On the Conejos river near Mogote;

(c) On the Los Pinos river near Ortiz;

(d) On the San Antonio river at Ortiz;

(e) On the Conejos river at its mouths near Los Sauces;

(f) On the Rio Grande near Lobatos;

(g) On the Rio Chama below El Vado reservoir;

(h) On the Rio Grande at Otowi bridge near San Ildefonso;

(i) On the Rio Grande near San Acacia;

(j) On the Rio Grande at San Marcial;

(k) On the Rio Grande below Elephant Butte reservoir;

(l) On the Rio Grande below Caballo reservoir.

Similar gauging stations shall be maintained and operated below any other reservoir constructed after 1929, and at such other points as may be necessary for the securing of records required for the carrying out of the compact; and automatic water stage recorders shall be maintained and operated on each of the reservoirs mentioned, and on all others constructed after 1929.

Such gauging stations shall be equipped, maintained and operated by the commission directly or in co-operation with an appropriate federal or state agency, and the equipment, method and frequency of measurement at such stations shall be such as to produce reliable records at all times.

ARTICLE III

The obligation of Colorado to deliver water in the Rio Grande at the Colorado-New Mexico state line, measured at or near Lobatos, in each calendar year, shall be ten thousand acre-feet less than the sum of those quantities set forth in the two following tabulations of relationship, which correspond to the quantities at the upper index stations:

Discharge of Conejos River
Quantities in Thousands of Acre-Feet

Conejos Index Supply (1)	Conejos River at Mouths (2)
100	0
150	20
200	45
250	75
300	109
350	147
400	188
450	232
500	278
550	326
600	376
650	426
700	476

Intermediate quantities shall be computed by proportional parts.

(1) Conejos index supply is the natural flow Conejos river at the U. S. G. S. gauging station near Mogote during the calendar year, plus the natural flow of Los Pinos river at the U. S. G. S. gauging station near Ortiz and the natural flow of San Antonio river at the U. S. G. S. gauging station at Ortiz, both during the months of April to October, inclusive.

(2) Conejos river at mouths is the combined discharge of branches of this river at the U. S. G. S. gauging stations near Los Sauces during the calendar year.

Discharge of Rio Grande Exclusive of Conejos River
Quantities in Thousands of Acre-Feet

Rio Grande at Del Norte (3)	Rio Grande at Lobatos Less Conejos at Mouths (4)
200	60
250	65
300	75
350	86
400	98
450	112
500	127
550	144
600	162
650	182
700	204
750	229
800	257
850	292
900	335
950	380
1,000	430
1,100	540
1,200	640
1,300	740
1,400	840

Intermediate quantities shall be computed by proportional parts.

(3) Rio Grande at Del Norte is the recorded flow of the Rio Grande at the U. S. G. S. gauging station near Del Norte during the calendar year (measured above all principal points of diversion to San Luis Valley) corrected for the operation of reservoirs constructed after 1937.

(4) Rio Grande at Lobatos less Conejos at mouths is the total flow of the Rio Grande at the U. S. G. S. gauging station near Lobatos, less the discharge of Conejos river at its mouths, during the calendar year.

The application of these schedules shall be subject to the provisions hereinafter set forth and appropriate adjustments shall be made for (a) any change in location of gauging stations; (b) any new or increased depletion of the runoff above inflow index gauging stations; and (c) any transmountain diversions into the drainage basin of the Rio Grande above Lobatos.

In event any works are constructed after 1937 for the purpose of delivering water into the Rio Grande from the closed basin, Colorado shall not be credited with the amount of such water delivered unless the proportion of sodium ions shall be less than forty-five per cent of the total positive ions in that water when the total dissolved solids in such water exceeds three hundred fifty parts per million.

ARTICLE IV

The obligation of New Mexico to deliver water in the Rio Grande at San Marcial, during each calendar year, exclusive of the months of July, August and September, shall be that quantity set forth in the following tabulation of relationship, which corresponds to the quantity at the upper index station:

Discharge of Rio Grande at Otowi Bridge
And at San Marcial Exclusive of July,
August and September
Quantities in Thousands of Acre-Feet

Otowi Index Supply (5)	San Marcial Index Supply (6)
100	0
200	65
300	141
400	219
500	300
600	383
700	469
800	557
900	648
1000	742
1100	839
1200	939
1300	1042
1400	1148
1500	1257
1600	1370

Otowi Index Supply (5)	San Marcial Index Supply (6)
1700	1489
1800	1608
1900	1730
2000	1856
2100	1985
2200	2117
2300	2253

Intermediate quantities shall be computed by proportional parts.

(5) The Otowi index supply is the recorded flow of the Rio Grande at the U. S. G. S. gauging station at Otowi Bridge near San Ildefonso (formerly station near Buckman) during the calendar year, exclusive of the flow during the months of July, August and September, corrected for the operation of reservoirs constructed after 1929 in the drainage basin of the Rio Grande between Lobatos and Otowi Bridge.

(6) San Marcial index supply is the recorded flow of the Rio Grande at the gauging station at San Marcial during the calendar year exclusive of the flow during the months of July, August and September.

The application of this schedule shall be subject to the provisions hereinafter set forth and appropriate adjustments shall be made for (a) any change in location of gauging stations; (b) depletion after 1929 in New Mexico at any time of the year of the natural runoff at Otowi Bridge; (c) depletion of the runoff during July, August and September of tributaries between Otowi Bridge and San Marcial, by works constructed after 1937; and (d) any transmountain diversions into the Rio Grande between Lobatos and San Marcial.

Concurrent records shall be kept of the flow of the Rio Grande at San Marcial, near San Acacia, and of the release from Elephant Butte reservoir, to the end that the records at these three stations may be correlated.

ARTICLE V

If at any time it should be the unanimous finding and determination of the commission that because of changed physical conditions, or for any other reason, reliable records are not obtainable, or cannot be obtained, at any of the stream gauging stations herein referred to, such stations may, with the unanimous approval of the Commission, be abandoned, and with such approval another station, or other stations, shall be established and new measurements shall be substituted which, in the unanimous opinion of the commission, will result in substantially the same results, so far as the rights and obligations to deliver water are concerned, as would have existed if such substitution of stations and measurements had not been so made.

ARTICLE VI

Commencing with the year following the effective date of this compact, all credits and debits of Colorado and New Mexico shall be computed for each calendar year; provided, that in a year of actual spill no annual credits nor annual debits shall be computed for that year.

In the case of Colorado, no annual debit nor accrued debit shall exceed 100,000 acre-feet, except as either or both may be caused by holdover storage of water in reservoirs constructed after 1937 in the drainage basin of the Rio Grande above Lobatos. Within the physical limitations of storage capacity in such reservoirs, Colorado shall retain water in storage at all times to the extent of its accrued debit.

In the case of New Mexico, the accrued debit shall not exceed 200,000 acre-feet at any time, except as such debit may be caused by holdover storage of water in reservoirs constructed after 1929 in the drainage basin of the Rio Grande between Lobatos and San Marcial. Within the physical limitations of storage capacity in such reservoirs, New Mexico shall retain water in storage at all times to the extent of its accrued debit. In computing the magnitude of accrued credits or debits, New Mexico shall not be charged with any greater debt in any one year than the sum of 150,000 acre-feet and all gains in the quantity of water in storage in such year.

The commission by unanimous action may authorize the release from storage of any amount of water which is then being held in storage by reason of accrued debits of Colorado or New Mexico; provided, that such water shall be replaced at the first opportunity thereafter.

In computing the amount of accrued credits and accrued debits of Colorado or New Mexico, any annual credits in excess of 150,000 acre-feet shall be taken as equal to that amount.

In any year in which actual spill occurs, the accrued credits of Colorado, or New Mexico, or both, at the beginning of the year shall be reduced in proportion to their respective credits by the amount of such actual spill; provided, that the amount of actual spill shall be deemed to be increased by the aggregate gain in the amount of water in storage, prior to the time of spill, in reservoirs above San Marcial constructed after 1929; provided, further, that if the commissioners for the states having accrued credits authorized the release of part, or all, of such credits in advance of spill, the amount so released shall be deemed to constitute actual spill.

In any year in which there is actual spill of usable water, or at the time of hypothetical spill thereof, all accrued debits of Colorado, or New Mexico, or both, at the beginning of the year shall be cancelled.

In any year in which the aggregate of accrued debits of Colorado and New Mexico exceeds the minimum unfilled capacity of project storage, such debits shall be reduced proportionally to an aggregate amount equal to such minimum unfilled capacity.

To the extent that accrued credits are impounded in reservoirs between San Marcial and Courchesne, and to the extent that accrued debits are impounded in reservoirs above San Marcial, such credits and debits shall be reduced annually to compensate for evaporation losses in the proportion that such credits or debits bore to the total amount of water in such reservoirs during the year.

ARTICLE VII

Neither Colorado nor New Mexico shall increase the
nt of water in storage in reservoirs constructed after
whenever there is less than 400,000 acre feet of
le water in project storage; provided, that if the
al releases of usable water from the beginning of the
ndar year following the effective date of this Compact,
rom the beginning of the calendar year following actual
1, have aggregated more than an average of 790,000 acre
per annum, the time at which such minimum stage is
hed shall be adjusted to compensate for the difference
een the total actual release and releases at such
age rate; provided, further, that Colorado, or New
co, or both, may relinquish accrued credits at any time,
Texas may accept such relinquished water, and in such
t the state, or states, so relinquishing shall be
tled to store water in the amount of the water so
nquished.

ARTICLE VIII

During the month of January of any year the Commis-
r for Texas may demand of Colorado and New Mexico, and
Commissioner for New Mexico may demand of Colorado, the
ase of water from storage reservoirs constructed after
to the amount of the accrued debits of Colorado and
Mexico, respectively, and such releases shall be made
ach at the greatest rate practicable under the condi-
s then prevailing, and in proportion to the total debit
ach, and in amounts, limited by their accrued debits,
icient to bring the quantity of usable water in project
age to 600,000 acre feet by March first and to maintain
quantity in storage until April thirtieth, to the end
a normal release of 790,000 acre feet may be made from
ect storage in that year.

ARTICLE IX

Colorado agrees with New Mexico that in event the
ed States or the State of New Mexico decides to con-
ct the necessary works for diverting the waters of the
Juan River, or any of its tributaries, into the Rio
de, Colorado hereby consents to the construction of
works and the diversion of waters from the San Juan
River, or the tributaries thereof, into the Rio Grande in New Mexico, provided the present and prospective uses of water in Colorado by other diversions from the San Juan River, or its tributaries, are protected.

ARTICLE X

In the event water from another drainage basin shall be imported into the Rio Grande Basin by the United States or Colorado or New Mexico, or any of them jointly, the State having the right to the use of such water shall be given proper credit therefor in the application of the schedules.

ARTICLE XI

New Mexico and Texas agree that upon the effective date of this Compact all controversies between said States relative to the quantity or quality of the water of the Rio Grande are composed and settled; however, nothing herein shall be interpreted to prevent recourse by a signatory state to the Supreme Court of the United States for redress should the character or quality of the water, at the point of delivery, be changed hereafter by one signatory state to the injury of another. Nothing herein shall be construed as an admission by any signatory state that the use of water for irrigation causes increase of salinity for which the user is responsible in law.

ARTICLE XII

To administer the provisions of this Compact there shall be constituted a Commission composed of one representative from each state, to be known as the Rio Grande Compact Commission. The State Engineer of Colorado shall be ex-officio the Rio Grande Compact Commissioner for Colorado. The State Engineer of New Mexico shall be ex-officio the Rio Grande Compact Commissioner for New Mexico. The Rio Grande Compact Commissioner for Texas shall be appointed by the Governor of Texas. The President of the United States shall be requested to designate a representative of the United States to sit with such Commission, and such representative of the United States, if so designated by the President, shall act as Chairman of the Commission without vote.

The salaries and personal expenses of the Rio Grande Compact Commissioners for the three States shall be paid by their respective States, and all other expenses incident to the administration of this Compact, not borne by the United States, shall be borne equally by the three States.

In addition to the powers and duties hereinbefore
cifically conferred upon such Commission, and the members
reof, the jurisdiction of such Commission shall extend
y to the collection, correlation and presentation of
tual data and the maintenance of records having a
ring upon the administration of this Compact, and, by
nimous action, to the making of recommendations to the
pective States upon matters connected with the adminis-
tion of this Compact. In connection therewith, the
mission may employ such engineering and clerical aid as
be reasonably necessary within the limit of funds
vided for that purpose by the respective States. Annual
orts compiled for each calendar year shall be made by
Commission and transmitted to the Governors of the
natory States on or before March first following the
r covered by the report. The Commission may, by unani-
s action, adopt rules and regulations consistent with
provisions of this Compact to govern their proceedings.

The findings of the Commission shall not be conclusive
any court or tribunal which may be called upon to inter-
t or enforce this Compact.

ARTICLE XIII

At the expiration of every five-year period after the
ective date of this Compact, the Commission may, by
nimous consent, review any provisions hereof which are
substantive in character and which do not affect the
ic principles upon which the Compact is founded, and
ll meet for the consideration of such questions on the
uest of any member of the Commission; provided, however,
t the provisions hereof shall remain in full force and
ect until changed and amended within the intent of the
pact by unanimous action of the Commissioners, and until
changes in this Compact are ratified by the legislatures
the respective states and consented to by the Congress,
the same manner as this Compact is required to be
ified to become effective.

ARTICLE XIV

The schedules herein contained and the quantities of
er herein allocated shall never be increased nor dimin-
ed by reason of any increase or diminution in the
ivery or loss of water to Mexico.

ARTICLE XV

The physical and other conditions characteristic of the Rio Grande and peculiar to the territory drained and served thereby, and to the development thereof, have actuated this Compact and none of the signatory states admits that any provisions herein contained establishes any general principle or precedent applicable to other interstate streams.

ARTICLE XVI

Nothing in this Compact shall be construed as affecting the obligations of the United States of America to Mexico under existing treaties, or to the Indian Tribes, or as impairing the rights of the Indian Tribes.

ARTICLE XVII

This Compact shall become effective when ratified by the legislatures of each of the signatory states and consented to by the Congress of the United States. Notice of ratification shall be given by the Governor of each state to the Governors of the other states and to the President of the United States, and the President of the United State is requested to give notice to the Governors of each of the signatory states of the consent of the Congress of the United States.

IN WITNESS WHEREOF, the Commissioners have signed this Compact in quadruplicate original, one of which shall be deposited in the archives of the Department of State of the United States of America and shall be deemed the authoritative original, and of which a duly certified copy shall be forwarded to the Governor of each of the signatory States.

Done at the City of Santa Fe, in the State of New ico, on the 18th day of March, in the year of our Lord, Thousand Nine Hundred and Thirty-eight.

(Sgd.) M. C. HINDERLIDER
(Sgd.) THOMAS M. McCLURE
(Sgd.) FRANK B. CLAYTON

OVED:
(Sgd.) S. O. HARPER

FIED BY:

Colorado, February 21, 1939
New Mexico, March 1, 1939
Texas, March 1, 1939

ssed Congress as Public Act No. 96, 76th Congress, proved by the President May 31, 1939.

RESOLUTION ADOPTED BY RIO GRANDE COMPACT COMMISSION AT THE ANNUAL MEETING HELD AT EL PASO, TEXAS, FEBRUARY 22-24, 1948, CHANGING GAGING STATIONS AND MEASUREMENTS OF DELIVERIES BY NEW MEXICO

R E S O L U T I O N

Whereas, at the Annual Meeting of the Rio Grande Compact Commission in the year 1945, the question was raised as to whether or not a schedule for delivery of water by New Mexico during the entire year could be worked out, and

Whereas, at said meeting the question was referred to the Engineering Advisers for their study, recommendations and report, and

Whereas, said Engineering Advisers have met, studied the problems and under date of February 24, 1947, did submit their Report, which said Report contains the findings of said Engineering Advisers and their recommendations, and

Whereas, the Compact Commission has examined said Report and finds that the matters and things therein found and recommended are proper and within the terms of the Rio Grande Compact, and

Whereas, the Commission has considered said Engineering Advisers' Report and all available evidence, information and material and is fully advised:

Now, Therefore, Be it Resolved:

The Commission finds as follows:

(a) That because of change of physical conditions, reliable records of the amount of water passing San Marcial are no longer obtainable at the stream gaging station at San Marcial and that the same should be abandoned for Compact purposes.

(b) That the need for concurrent records at San Marcial and San Acacia no longer exists and that the gaging station at San Acacia should be abandoned for Compact purposes.

(c) That it is desirable and necessary that the obligations of New Mexico under the Compact to deliver water in the months of July, August, September, should be scheduled.

(d) That the change in gaging stations and substitution of the new measurements as hereinafter set forth will result in substantially the same results so far as the rights and obligations to deliver water are concerned, and would have existed if such substitution of stations and measurements had not been so made.

Be it Further Resolved:

That the following measurements and schedule thereof shall be substituted for the measurements and schedule thereof as now set forth in Article IV of the Compact:

"The obligation of New Mexico to deliver water in the Rio Grande into Elephant Butte Reservoir during each calendar year shall be measured by that quantity set forth in the following tabulation of relationship which corresponds to the quantity at the upper index station:

DISCHARGE OF RIO GRANDE AT OTOWI BRIDGE AND ELEPHANT BUTTE EFFECTIVE SUPPLY

Quantities in thousands of acre-feet

i Index Supply (5)	Elephant Butte Effective Index Supply (6)
100	57
200	114
300	171
400	228
500	286
600	345
700	406
800	471
900	542
1,000	621
1,100	707
1,200	800
1,300	897
1,400	996
1,500	1,095
1,600	1,195
1,700	1,295
1,800	1,395
1,900	1,495
2,000	1,595

DISCHARGE OF RIO GRANDE AT OTOWI BRIDGE AND ELEPHANT BUTTE EFFECTIVE SUPPLY--Continued

Quantities in thousands of acre-feet

Otowi Index Supply (5)	Elephant Butte Effective Index Supply (6)
2,100	1,695
2,200	1,795
2,300	1,895
2,400	1,995
2,500	2,095
2,600	2,195
2,700	2,295
2,800	2,395
2,900	2,495
3,000	2,595

Intermediate quantities shall be computed by proportional parts.

(5) The Otowi Index Supply is the recorded flow of the Rio Grande at the U.S.G.S. gaging station at Otowi Bridge near San Ildefonso (formerly station near Buckman) during the calendar year, corrected for the operation of reservoirs constructed after 1929 in the drainage basin of the Rio Grande between Lobatos and Otowi Bridge.

(6) Elephant Butte Effective Index Supply is the recorded flow of the Rio Grande at the gaging station below Elephant Butte Dam during the calendar year plus the net gain in storage in Elephant Butte Reservoir during the same year or minus the net loss in storage in said reservoir, as the case may be.

The application of this schedule shall be subject to the provisions hereinafter set forth and appropriate adjustments shall be made for (a) any change in location of gaging stations; (b) depletion after 1929 in New Mexico of the natural runoff at Otowi Bridge; and (c) any transmountain diversions into the Rio Grande between Lobatos and Elephant Butte Reservoir."

Be it Further Resolved:

That the gaging stations at San Acacia and San Marcial be, and the same are hereby abandoned for Compact purposes.

Be it Further Resolved:

That this Resolution has been passed unanimously and shall be effective January 1, 1949, if within 120 days from this date the Commissioner for each State shall have received from the Attorney General of the State represented by him, an opinion approving this Resolution, and shall have so advised the Chairman of the Commission, otherwise, to be of no force and effect.

(Note: The following paragraph appears in the Minutes of the Annual Meeting of the Commission held at Denver, Colorado, February 14-16, 1949:

"The Chairman announced that he had received, pursuant to the Resolution adopted by the Commission at the Ninth Annual Meeting on February 24, 1948, opinions from the Attorneys General of Colorado, New Mexico and Texas that the substitution of stations and measurements of deliveries by New Mexico set forth in said resolution was within the powers of the Commission").

1968 COMPACT STIPULATION

TEXAS AND NEW MEXICO v. COLORADO

MOTION FOR CONTINUANCE

COME NOW the States of Colorado, Texas and New Mexico and respectfully move the Court to issue its order continuing this cause until such time as the plaintiff states may advise this Court of their desire that the cause should proceed toward judgment and as their grounds therefor submit the attached memorandum.

The States of Colorado, Texas and New Mexico advise the Court that the following agreement has been reached among the parties in this cause.

1. The State of Colorado undertakes to deliver water at the Colorado—New Mexico state line to meet every year the delivery obligation established by the schedules of Article III of the Rio Grande Compact. To this end the State of Colorado shall exercise its best efforts and use all available administrative and legal powers including, if necessary, the curtailment of diversions enforced by agents of the State. The State of Colorado shall make frequent and regular reports to the plaintiffs of all measures taken to effect compliance.

2. The State of Colorado desires to request that the Court continue this matter until such time as the plaintiff states may advise the Court that the continuance should terminate and the cause proceed toward judgment.

3. The States of Texas and New Mexico advise the Court of their concurrence in the request for the continuance in order to provide to the State of Colorado an opportunity to demonstrate its willingness and ability to deliver water at the Colorado-New Mexico state line annually in accordance with Article III, subject to the condition that such continuance terminate whenever the plaintiff states shall communicate in writing to the State of Colorado and to the Court their belief that the defendant has failed to deliver water at the Colorado-New Mexico state line in accordance with the undertaking set out in Paragraph 1 above, or that the State of Colorado has failed to take effective actions reasonably calculated to implement that undertaking. After the giving of such notice, the plaintiff states shall have sixty (60) days within which to reply to the Colorado counterclaim or to otherwise plead as may be appropriate.

Nothing contained herein shall be construed to waive any right, claim or defense already pleaded by any party, or which may be pleaded hereafter by any party in the event the continuance is terminated.

The States of Colorado, Texas and New Mexico, therefore, join in requesting that the Court continue this matter pursuant to the terms of the agreement set out above.

ORDER

391 U.S. 901 (May 6, 1968.)

No 29. Orig. Texas et al. v. Colorado. Motion of the United States for leave to intervene as plaintiff granted. Joint motion of Texas, New Mexico, and Colorado for continuance granted. Mr. Justice Marshall took no part in the consideration or decision of these motions. Solicitor General Griswold on the motion for the United States. Crawford C. Martin, Attorney General, for the State of Texas, Boston E. Witt, Attorney General, for the State of New Mexico, and Duke W. Dunbar, Attorney General, for the State of Colorado, on the joint motion.

APPENDIX B

SUMMARY TABLES OF HYDROLOGIC INPUT DATA

Total Volume of Increased Streamflow — Highest Level of Treatment

Basin	Rio Grande Res.			Continental Res.			Santa Maria Res.			Del Norte Gage			Platoro Res.			Mogote Gage		
Elev (ft)	11,580			11,160			11,160			10,241			10,900			10,075		
Area (Ac)	49,280			31,470			43,600			514,765			13,545			81,490		
Year	P (in)	RO (in)	U (ac-ft)	P (in)	RO (in)	U (ac-ft)	P (in)	RO (in)	U (ac-ft)	P (in)	RO (in)	U (ac-ft)	P (in)	RO (in)	U (ac-ft)	P (in)	RO (in)	U (ac-ft)
1968	29.85	3.36	13,798	27.40	3.17	8313	27.71	3.19	11,590	23.62	2.36	101,237	26.38	3.09	3488	22.18	2.25	15,279
1969	31.30	3.45	14,168	28.85	3.30	8654	29.16	3.33	12,099	24.47	2.45	105,098	27.83	3.20	3,612	23.63	2,37	16091
1970	31.45	3.45	14,168	29.00	3.32	8,707	29.31	3.34	12,135	24.62	2.46	105,527	27.98	3.21	3623	23.78	2.38	16,162
1971	27.25	3.16	12,977	24.80	2.96	7,763	25.11	3.00	10900	20.42	2.10	90,089	23.78	2,89	3262	19.58	2.01	13,853
1972	26.75	3.10	12731	24.30	2.93	7684	24.66	2.95	10,718	19.92	2,07	88,797	23.28	2,86	3,228	19.08	1.99	13,514
1973	31.40	3.46	14,209	28.95	3.32	8,707	29.26	3.33	12099	24.57	2.46	105,527	27.93	3.21	3623	23.73	2.39	16,230
1974	23.55	2.87	11,786	21.10	2.65	6950	21.41	2.68	9737	16.72	1.72	73,783	20.08	2.60	2935	15.88	1.60	10,865
1975	31.95	3.46	14,209	29.50	3.35	8785	29.81	3.37	12,244	25.12	2.54	108,759	28.48	3.28	3,702	24.28	2,42	16,434
1976	26.50	3.10	12,731	24.65	2.92	7658	24.36	2.93	10,646	19.67	2,05	87,939	23,03	2,85	3,217	18.83	1.96	13,310
1977	25.00	2.99	12,279	22.55	2.83	7,422	22.86	2.84	10,319	18.17	1.90	81,504	21.53	2,69	3036	17.33	1.80	12,224
1978	26.35	3.09	12,690	23.90	2.90	7605	24.21	2.93	10,319	19.52	2.04	87,510	22.88	2.80	3,161	18.68	1.95	13,242
1979	32.65	3.53	14,496	30.20	3.39	8890	30.51	3.40	12,353	25.80	2.57	110,246	29.18	3.33	3759	24.98	2.48	16,841
1980	28.37	3.26	13,388	25.92	3.07	8051	26.23	3.09	11,227	21.54	2.19	93,945	24.90	2.97	3352	20.70	2.12	14,397
1981	28.35	3.26	13,388	25.90	3.07	8,051	26.21	3.09	11,227	21.52	2.19	93,945	24.88	2.97	3,352	20.68	2.12	14,397
1982	31.15	3.44	14,127	28.70	3.29	8628	27.01	3.33	12,063	24.32	2.13	104,240	27.68	3.19	3601	23.48	2.36	16,026

P = Annual Precipitation (water Year)
RO = Runoff Increase
U = Volume of Runoff Increase

Seasonal Distribution of Increased Streamflow

(Highest Level of Treatment)

Year	Basin	Flow Per Period (cfs)			
		April 15-30	May 1-15	May 16-31	June 1-15
1968	Rio Grande Res. (RGR)	21.74	115.94	195.65	115.94
	Continental Res. (CR)	13.10	69.85	117.88	69.85
	Santa Maria Res. (SMR)	18.26	97.39	164.34	97.39
	Del Norte Gage (DNG)	159.50	850.67	1435.51	850.50
	Total	212.60	1133.85	1913.38	1133.85
	Platoro Res. (PR)	5.50	29.31	49.46	29.31
	Mogote Gage (MG)	24.07	128.39	216.65	128.39
	Total	29.57	157.69	266.11	157.69
1969	Rio Grande Res.	22.32	119.05	200.90	119.05
	Continental Res.	13.63	72.72	122.71	72.72
	Santa Maria Res.	19.06	101.67	171.56	101.67
	Del Norte Gage	165.58	883.12	1490.26	883.12
	Total	220.60	1176.55	1985.43	1176.55
	Platoro Res.	5.69	30.35	51.22	30.35
	Mogote Gage	25.36	135.23	228.21	135.23
	Total	31.05	165.59	279.42	165.59
1970	Rio Grande Res.	22.32	119.05	200.90	119.05
	Continental Res.	13.72	73.16	123.46	73.16
	Santa Maria Res.	19.12	101.97	172.07	101.97
	Del Norte Gage	166.26	886.72	1496.34	886.72
	Total	221.42	1180.90	1992.77	1180.90
	Platoro Res.	5.71	30.44	51.37	30.44
	Mogote Gage	25.46	135.81	229.17	135.81
	Total	31.17	166.25	280.55	166.25
1971	Rio Grande Res.	20.45	109.04	184.01	109.04
	Continental Res.	12.23	65.23	110.08	65.23
	Santa Maria Res.	17.17	91.58	154.56	91.58
	Del Norte Gage	141.93	756.96	1277.36	756.96
	Total	191.78	1022.82	1726.01	1022.82
	Platoro Res.	5.14	27.41	46.25	27.41
	Mogote Gage	21.83	116.40	196.43	116.40
	Total	26.97	143.81	242.69	143.81

Seasonal Distribution of Increased Streamflow

(Highest Level of Treatment)

Year	Basin	Flow Per Period (cfs)			
		April 15-30	May 1-15	May 16-31	June 1-15
1972	Rio Grande Res (RGR)	20.06	106.98	180.57	106.98
	Continental Res (CR)	12.11	64.57	108.96	64.57
	Santa Maria Res (SMR)	16.89	90.06	151.98	90.06
	Del Norte Gage (DNG)	139.90	746.14	1259.11	746.14
	Total	188.95	1007.75	1700.57	1007.75
	Platoro Res. (PR)	5.09	27.12	45.77	27.12
	Mogote Gage (MG)	21.29	113.56	191.62	113.56
	Total	26.38	140.68	237.40	140.68
1973	Rio Grande Res.	22.39	119.40	201.48	119.40
	Continental Res.	13.72	73.16	123.46	73.16
	Santa Maria Res.	19.06	101.67	171.56	101.67
	Del Norte Gage	166.26	886.72	1496.34	886.72
	Total	221.43	1180.94	1992.84	1180.94
	Platoro Res.	5.71	30.44	51.37	30.44
	Mogote Gage	25.57	136.38	230.14	136.38
	Total	31.28	166.82	281.51	166.82
1974	Rio Grande Res.	18.57	99.04	167.12	99.04
	Continental Res.	10.95	58.40	98.55	58.40
	Santa Maria Res.	15.34	81.82	138.07	81.82
	Del Norte Gage	116.25	619.98	1046.22	619.98
	Total	192.39	859.23	1449.96	859.23
	Platoro Res	4.62	24.66	41.62	24.66
	Mogote Gage	17.12	91.30	154.06	91.30
	Total	21.74	115.96	195.68	115.96
1975	Rio Grande Res.	22.39	119.40	201.48	119.40
	Continental Res.	13.84	73.82	124.57	73.82
	Santa Maria Res.	19.39	102.88	173.62	102.88
	Del Norte Gage	171.67	915.56	1545.60	915.56
	Total	227.19	1211.66	2044.67	1211.66
	Platoro Res.	5.83	31.11	52.49	31.11
	Mogote Gage	25.89	138.09	233.03	138.09
	Total	31.72	169.20	285.52	169.20

Seasonal Distribution of Increased Streamflow

(Highest level of Treatment)

Year	Basin	Flow Per Period (cfs) April 15-30	May 1-15	May 16-31	June 1-15
1976	Rio Grande Res (RGR)	20.06	106.98	180.52	106.98
	Continental Res. (CR)	12.07	64.35	108.59	64.35
	Santa Maria Res (SMR)	16.77	89.46	150.96	89.46
	Del Norte Gage (DN)	138.55	738.93	1246.95	738.93
	Total	187.45	999.71	1687.01	999.71
	Platoro Res (PR)	5.07	27.03	45.62	27.03
	Mogote Gage (MG)	20.97	111.84	188.73	111.84
	Total	26.04	138.87	234.35	138.87
1977	Rio Grande Res.	19.35	103.18	174.11	103.18
	Continental Res	11.69	62.37	105.24	62.37
	Santa Maria Res	16.26	86.71	146.32	86.71
	Del Norte Gage	128.41	684.86	1155.70	684.86
	Total	175.71	937.11	1581.38	937.11
	Platoro Res	4.78	25.51	43.05	25.51
	Mogote Gage	19.26	102.72	173.33	102.72
	Total	24.04	128.23	216.38	128.23
1978	Rio Grande Res.	19.99	106.63	179.91	106.63
	Continental Res.	11.98	63.90	107.84	63.90
	Santa Maria Res.	16.26	86.71	146.32	86.71
	Del Norte Gage	137.87	735.33	1240.86	735.33
	Total	186.11	992.57	1674.96	992.57
	Platoro Res.	4.98	26.56	44.82	26.56
	Mogote Gage	20.86	111.27	187.77	111.27
	Total	25.84	137.83	232.59	137.83
1979	Rio Grande Res.	22.84	121.81	205.55	121.81
	Continental Res.	14.01	74.70	126.06	74.70
	Santa Maria Res.	19.46	103.80	175.16	103.80
	Del Norte Gage	173.69	926.37	1563.25	926.37
	Total	230.00	1226.68	2070.02	1226.68
	Platoro Res.	5.92	31.59	53.30	31.59
	Mogote Gage	26.53	141.51	238.80	141.51
	Total	32.46	173.10	292.10	173.10

Seasonal Distribution of Increased Streamflow

(Highest Level of Treatment)

Year	Basin	Flow Per Period (cfs) April 15-30	May 1-15	May 16-31	June 1-15
1980	Rio Grande Res. (RGR)	21.09	112.50	189.84	112.50
	Continental Res. (CR)	12.68	67.65	114.16	67.65
	Santa Maria Res. (SMR)	17.69	94.34	159.20	94.34
	Del Norte Gage (DNG)	148.01	789.49	1332.11	789.40
	Total	199.48	1063.88	1795.30	1065.88
	Platoro Res. (PR)	5.28	28.17	47.53	28.17
	Mogote Gage (MG)	22.68	120.97	204.14	120.97
	Total	27.96	149.14	251.68	149.14
1981	Rio Grande Res	Same as 1980			
	Continental Res				
	Santa Maria Res.				
	Del Norte Gage				
	Total				
	Platoro Res.				
	Mogote Gage				
	Total				
1982	Rio Grande Res	22.26	118.71	200.32	118.71
	Continental Res.	13.59	72.50	122.34	72.50
	Santa Maria Res.	19.01	101.36	171.05	101.36
	Del Norte Gage	164.23	875.91	1478.09	875.91
	Total	219.09	1168.47	1971.80	1168.47
	Platoro Res.	5.67	30.26	51.06	30.26
	Mogote Gage	25.25	134.66	227.24	134.66
	Total	30.92	164.92	278.30	164.92

Weekly Distribution of Increased Streamflow

Year	Basin	Flow Per Week (cfs) 1	2	3	4	5	6	7	8	9
1968	RGR	21.74	21.74	89.03	115.94	161.49	195.65	172.88	115.94	99.38
	CR	13.10	13.10	53.64	69.85	97.30	117.88	104.16	69.85	59.87
	SMR	18.26	18.26	74.78	97.39	135.65	164.34	145.21	97.39	83.48
	DNG	159.50	159.50	653.19	850.67	1184.86	1435.51	1268.36	850.50	729.00
	Total	212.60	212.60	870.64	1133.85	1579.30	1913.38	1690.61	1133.68	971.73
	PR	5.50	5.50	22.51	29.31	40.82	49.46	43.70	29.31	25.12
	MG	24.07	24.07	98.58	128.39	178.82	216.65	191.43	128.39	110.05
	Total	29.57	29.57	121.09	157.70	219.64	266.11	235.13	157.70	135.17
1969	RGR	Same as Week 3	22.32	91.41	119.05	165.82	200.90	177.51	119.05	102.04
	CR		13.63	55.84	72.72	101.29	122.71	108.43	72.72	62.33
	SMR		19.06	78.07	101.67	141.61	171.56	151.59	101.67	87.15
	DNG		165.58	678.11	883.12	1230.06	1490.26	1316.98	883.12	756.96
	Total		220.60	903.43	1176.55	1638.77	1985.43	1754.51	1176.55	1008.48
	PR		5.69	23.30	30.35	42.28	51.22	45.26	30.35	26.01
	MG		25.36	103.89	135.23	188.36	228.21	201.64	135.23	115.91
	Total		31.05	127.19	165.59	230.64	279.42	246.90	165.59	141.93
1970	RGR	Same as Week 3	22.32	91.41	119.05	165.82	200.90	177.51	119.05	102.04
	CR		13.72	56.18	73.16	102.07	123.76	109.30	73.16	62.71
	SMR		19.12	78.30	101.97	142.03	172.07	150.04	101.97	87.40
	DNG		166.26	680.57	886.72	1235.07	1496.34	1322.16	886.72	760.05
	Total		221.42	906.76	1180.90	1645.00	1992.77	1761.02	1180.90	1012.20
	PR		5.71	23.37	30.44	42.40	51.37	45.39	30.44	26.09
	MG		25.46	104.28	135.81	189.16	229.17	202.50	135.81	116.41
	Total		31.17	127.66	166.25	231.56	280.55	247.89	166.25	142.50
1971	RGR		20.45	83.73	109.04	151.88	184.01	162.59	109.64	93.46
	CR		12.23	50.09	65.23	90.86	110.08	97.27	65.23	55.91
	SMR		17.17	70.32	91.58	127.57	154.56	136.57	91.58	78.50
	DNG		141.93	581.21	756.96	1054.33	1277.36	1128.67	756.96	648.82
	Total		191.78	785.37	1022.82	1424.64	1726.01	1525.10	1022.82	876.69
	PR		5.14	21.05	27.41	38.18	46.25	40.87	27.41	23.49
	MG		21.83	89.38	116.40	162.13	196.43	173.56	116.40	99.77
	Total		26.97	110.43	143.81	200.31	242.69	214.43	143.81	123.27

Weekly Distribution of Increased Streamflow

Year	Basin	Flow Per Week (cfs) 1	2	3	4	5	6	7	8	9
	RGR		20.06	82.15	106.98	149.00	180.52	159.51	106.98	91.70
	CR		12.11	49.58	64.57	89.94	108.96	96.28	64.57	55.35
	SMR		16.89	69.15	90.06	100.66	151.98	134.29	90.06	77.19
	DNG		139.90	572.93	746.14	1039.27	1259.11	1112.55	746.14	639.55
1972	Tot.		188.95	773.81	1007.75	1403.65	1700.57	1502.62	1067.75	863.79
	PR		5.09	20.83	27.12	31.24	45.77	40.44	27.12	23.25
	MG		21.29	87.20	113.56	158.17	191.62	169.32	113.56	97.34
	Tot		26.38	108.02	140.68	184.33	237.40	209.76	140.68	120.58
	RGR		22.39	91.68	119.40	166.30	201.48	178.03	119.40	102.34
	CR		13.72	56.18	73.16	101.90	128.46	109.09	73.16	62.71
	SMR		19.06	78.07	101.67	141.61	171.56	151.59	101.67	87.15
	DNG		166.26	680.87	886.72	1235.07	1496.31	1322.16	886.72	760.05
1973	Tot.		221.43	906.80	1180.94	1644.89	1992.84	1760.87	1180.94	1012.24
	PR		5.71	23.37	30.41	42.40	51.37	45.39	30.44	26.09
	MG		25.57	104.72	136.38	189.96	230.19	203.35	136.38	116.90
	Tot		31.28	128.09	166.80	232.36	281.51	248.74	166.82	142.99
	RGR		18.57	76.05	99.04	99.50	167.12	147.67	99.04	84.89
	CR		10.95	44.84	58.40	81.34	98.55	87.08	58.40	50.06
	SMR		15.34	62.83	81.82	113.96	138.07	122.00	81.82	70.13
	DNG		116.25	476.06	619.98	863.55	1046.22	924.44	619.98	531.41
1974	Tot		192.39	668.78	859.23	1158.35	1449.96	1281.18	859.23	736.49
	PR		4.62	18.93	24.66	34.35	41.62	36.77	24.66	21.14
	MG		17.12	70.11	91.30	127.16	154.06	136.13	91.30	78.26
	Tot		21.74	89.04	115.96	161.51	195.68	172.90	115.96	99.39
	RGR		22.39	91.68	119.40	166.30	201.48	178.03	119.40	102.34
	CR		13.84	56.68	73.82	102.82	124.57	110.07	73.82	63.27
	SMR		19.29	79.00	102.88	143.30	173.62	153.41	102.88	88.18
	DNG		171.67	703.02	915.56	1275.21	1545.00	1365.16	915.56	784.77
1975	Tot.		227.19	930.38	1211.66	1687.67	2044.67	1806.67	1211.66	1038.57
	PR		5.83	23.89	31.11	43.33	52.49	46.38	31.11	26.67
	MG		25.89	106.03	138.09	192.34	233.03	205.90	138.09	118.36
	Tot		31.72	129.92	169.20	235.67	285.52	252.29	169.20	145.03

Same as Week 1

Weekly Distribution of Increased Streamflow

Year	Basin	Flow Per Week (cfs) 1	2	3	4	5	6	7	8	9
	RGR		20.06	82.15	106.98	149.00	180.52	159.51	106.98	91.70
	CR		12.07	49.41	64.35	89.63	108.59	95.95	64.35	55.16
	SMR		16.77	68.69	89.46	124.60	150.96	133.39	89.46	76.68
	DNG	____	138.55	567.24	738.71	1029.13	1246.95	1101.80	738.93	633.18
1976	Tot		187.45	767.64	999.71	1392.45	1687.01	1490.65	999.71	856.71
	PR	Same as Week 2	5.07	20.76	27.03	37.65	45.62	40.31	27.03	23.17
	MG		20.97	85.86	111.81	155.78	188.73	166.76	111.81	98.84
	Tot		26.04	106.61	138.87	193.43	234.35	207.07	138.87	119.01
	RGR		19.35	79.73	103.18	142.71	174.11	153.84	103.18	88.44
	CR		11.69	47.89	62.37	86.87	105.24	92.99	62.37	53.46
	SMR		16.26	66.58	86.71	120.77	146.32	129.29	86.71	74.32
	DNG		126.41	525.87	684.86	953.91	1155.70	1021.17	684.86	587.02
1977	Tot		175.71	719.57	937.11	1305.26	1581.38	1397.29	937.11	803.25
	PR		4.78	19.59	25.51	35.53	43.05	38.04	25.51	21.87
	MG	____	19.26	78.87	102.72	143.07	173.33	153.16	102.72	88.05
	Tot		24.04	98.46	128.23	178.60	216.38	191.19	128.23	109.91
	RGR		19.99	81.88	106.63	148.52	179.94	158.99	106.63	91.40
	CR		11.98	49.07	63.90	89.01	107.81	95.29	63.90	54.77
	SMR		16.26	66.58	86.71	120.77	146.32	129.29	86.71	74.32
	DNG	____	137.87	564.63	735.33	1024.20	1240.86	1096.42	735.53	630.28
1978	Tot		186.11	762.15	992.57	1382.51	1674.96	1479.99	992.57	850.77
	PR		4.78	20.39	26.56	36.99	44.82	39.60	26.56	22.77
	MG	____	20.86	85.44	111.27	154.98	187.77	165.91	111.27	95.37
	Tot		25.64	105.83	137.83	191.98	232.59	205.52	137.83	118.14
	RGR		22.84	93.53	121.81	169.66	205.55	181.62	121.81	104.41
	CR		14.01	57.36	74.70	104.05	126.06	111.39	74.70	64.03
	SMR		19.46	79.70	103.80	144.58	175.16	154.77	103.80	88.97
	DNG	____	173.69	711.32	926.37	1290.30	1563.25	1381.28	926.37	794.03
1979	Tot		230.00	941.91	1226.68	1708.59	2070.00	1829.07	1226.68	1051.44
	PR		5.92	24.26	31.59	44.00	53.36	47.10	31.59	27.08
	MG	____	26.53	108.66	141.51	197.10	238.80	211.00	141.51	121.29
	Tot		32.46	132.91	173.10	241.10	292.10	258.10	173.10	148.37

Weekly Distribution of Increased Streamflow

Year	Basin	Flow Per Week (cfs) 1	2	3	4	5	6	7	8	9
	RGR		21.09	86.38	112.50	156.69	189.84	167.74	112.50	96.43
	CR		12.68	51.94	67.65	94.23	114.16	100.87	67.65	57.99
	SMR		17.69	72.44	94.34	131.40	159.20	140.67	94.34	80.86
	DNG	____	148.01	606.15	789.40	1099.52	1330.11	1177.05	789.40	676.63
1980	Tot		199.48	816.91	1063.88	1479.84	1795.30	1586.33	1063.88	911.91
	PR	Same as Week 1	5.28	21.63	28.17	39.23	47.53	42.00	28.17	24.15
	MG		22.68	92.89	120.97	168.50	204.14	180.38	120.97	103.69
	Tot		27.96	114.52	149.14	207.73	251.68	222.38	149.14	127.83
	RGR									
	CR									
	SMR									
	DNG	____	____	____	____	____	____	____	____	____
1981	Tot									
	PR									
	MG	____	____	____	____	____	____	____	____	____
	Tot									
	RGR		22.26	91.15	118.71	165.34	200.32	177.00	118.71	101.75
	CR		13.39	55.67	72.50	100.98	122.34	108.10	72.50	62.14
	SMR		19.01	77.83	101.36	141.18	171.05	151.14	101.36	86.88
	DNG	____	169.23	670.57	873.91	1220.01	1478.09	1306.04	875.91	750.78
1982	Tot		219.09	897.23	1168.47	1627.52	1971.80	1742.28	1168.47	1001.55
	PR		5.67	23.23	30.26	42.15	51.06	45.14	30.26	25.94
	MG	____	25.25	103.40	134.66	187.56	227.21	200.79	134.66	115.42
	Tot		30.92	126.63	164.92	229.71	278.30	245.91	164.92	141.36

Compact Deliveries — Conejos River

Year	Historical Flow Conejos Index Supply*	Increased Streamflow Level of Treatment (%) 100	50	10	Historical Scheduled Delivery*	New Scheduled Delivery Level of Treatment (%) 100	50	10	Incremental Increase Scheduled Delivery Level of Treatment (%) 100	50	10
1968	327,80	18,77	9,38	1,88	130,10	144,89	137,26	131,56	14,29	7,16	1,46
1969	383,90	19,71	9,85	1,97	174,80	191,18	182,88	176,41	16,38	8,08	1,61
1970	316,10	19,79	9,89	1,98	121,20	136,28	128,75	122,74	15,08	7,55	1,54
1971	221,20	17,12	8,56	1,71	57,70	67,99	62,86	58,75	10,29	5,16	1,05
1972	157,90	16,74	8,37	1,67	24,00	32,32	28,14	24,79	8,32	4,14	0,79
1973	447,20	19,85	9,93	11,99	229,50	247,69	238,56	230,75	18,19	9,06	1,25
1974	193,80	13,80	6,90	1,38	41,90	49,56	45,42	42,59	7,66	3,52	0,69
1975	416,40	20,14	10,07	2,01	202,40	220,16	211,29	204,20	17,76	8,89	1,80
1976	272,90	16,53	8,26	1,65	90,60	101,81	96,19	91,69	11,21	5,59	1,09
1977	96,40	15,26	7,63	1,53	0,00	4,66	1,61	0,00	4,66	1,61	0,00
1978	248,90	16,40	8,20	1,64	74,30	85,40	79,83	75,37	11,10	5,53	1,07
1979	476,90	20,60	10,30	2,06	256,70	275,70	266,22	258,64	19,00	9,52	1,94
1980	422,70	17,75	8,87	1,77	208,00	223,60	215,78	209,53	15,60	7,78	1,53
1981	169,80	17,75	8,87	1,77	29,90	38,78	34,34	30,79	8,88	4,44	0,89
1982	450,00	19,63	9,81	1,96	232,0	250,06	241,03	233,80	18,06	9,03	1,80

All Quantities in Thousands of Acre Feet
* From Rio Grande Compact Commission Reports

Compact Deliveries — Rio Grande Mainstem (Colorado)

Year	Historical Flow Rio Grande Index Supply*	Increased Streamflow Level of Treatment (%)			Historical Scheduled Delivery*	New Scheduled Delivery Level of Treatment (%)			Incremental Increase Scheduled Delivery Level of Treatment (%)		
		100	50	10		100	50	10	100	50	10
1968	669.00	134.94	67.47	13.49	190.40	259.76	222.24	196.30	69.36	31.84	5.90
1969	657.60	140.02	70.01	14.00	185.30	255.67	217.94	191.50	70.37	32.64	6.20
1970	654.70	140.54	70.27	14.05	184.10	254.33	216.49	190.25	70.23	32.39	6.15
1971	484.40	121.72	60.86	12.17	122.30	164.45	142.39	125.97	42.15	20.09	3.67
1972	477.30	119.93	59.97	11.99	120.20	161.00	139.67	123.71	40.80	19.37	3.59
1973	832.20	140.54	70.27	14.05	279.50	400.74	337.22	289.38	123.24	57.72	9.88
1974	337.50	102.26	51.13	10.23	83.20	109.13	95.27	85.50	25.93	12.07	2.30
1975	807.10	144.20	72.10	14.42	262.00	381.30	317.11	272.06	119.30	55.11	10.06
1976	589.90	118.97	59.49	11.90	158.40	208.44	181.76	162.72	50.04	23.36	4.32
1977	215.30	111.52	55.76	11.15	61.50	80.86	69.21	62.65	19.36	7.71	1.15
1978	406.10	118.12	59.06	11.81	99.70	135.23	116.55	103.01	35.53	16.85	3.31
1979	953.70	145.99	72.99	14.60	383.70	539.66	459.36	398.30	155.96	75.66	14.60
1980	750.10	126.61	63.31	12.66	229.10	314.97	266.39	236.15	85.87	37.29	7.05
1981	409.30	126.61	63.31	12.66	100.60	137.21	118.78	104.15	38.61	18.18	3.55
1982	697.5	139.06	69.53	13.91	202.90	282.59	238.54	209.71	79.69	35.64	6.81

All Quantities in Thousands of Acre feet

* From Rio Grande Compact Commission Reports

Compact Deliveries

Elephant Butte Res.

Year	Historical Flow Otowi Index Supply*	Increased Streamflow Level of Treatment (%) 100	50	10	Historical Scheduled Delivery*	New Scheduled Delivery Level of Treatment (%) 100	50	10	Incremental Increase Scheduled Delivery Level of Treatment (%) 100	50	10
1968	870.60	83.65	39.00	7.36	521.10	584.86	549.58	526.35	63.76	28.48	5.25
1969	1167.20	86.75	40.72	7.81	769.50	852.33	800.77	776.76	82.83	31.27	7.26
1970	832.20	85.31	39.94	7.69	493.90	555.83	522.22	499.32	61.93	28.32	5.42
1971	566.10	52.44	25.25	4.72	325.00	356.31	339.90	327.78	31.31	14.90	2.78
1972	474.30	49.12	23.51	4.38	271.10	299.82	284.73	273.63	28.72	13.63	2.53
1973	1576.30	141.43	66.78	11.13	1171.30	1312.73	1238.08	1182.43	141.43	66.78	11.13
1974	450.40	33.59	15.59	2.99	257.2	276.71	266.27	258.96	19.51	9.07	1.77
1975	1185.80	139.06	64.00	11.86	786.80	919.63	848.31	797.82	132.83	61.51	11.02
1976	682.50	61.25	28.95	5.41	395.30	434.44	413.44	398.63	39.14	18.14	3.33
1977	296.50	24.02	9.32	1.15	169.00	182.70	174.32	169.00	13.70	5.32	0.00
1978	697.00	46.63	22.38	4.38	405.40	435.62	419.90	408.20	30.22	14.50	2.80
1979	1888.70	174.96	85.18	16.54	1483.70	1658.66	1568.88	1500.24	174.96	85.18	16.54
1980	1392.20	101.47	45.07	8.58	988.30	1088.73	1032.90	996.77	100.43	44.60	8.47
1981	416.90	47.49	22.62	4.44	237.80	265.35	250.92	240.38	27.55	13.12	2.58
1982	1183.5	97.75	44.67	8.61	784.7	878.81	827.32	792.66	94.11	42.62	7.96

All Quantities in Thousands of Acre feet

* From Rio Grande Compact Commission Reports

Weekly Distribution of Compact Deliveries

Flow Per Week (cfs)

Level of Treatment		100%				50%				10%			
Year	Location	1-2	3-4	5-7	8-9	1-2	3-4	5-7	8-9	1-2	3-4	5-7	8-9
1968	Lasauses	23.16	108.10	183.60	108.10	11.61	54.16	91.99	54.16	2.37	11.04	18.76	11.04
	Stateline	112.44	524.70	891.15	524.70	51.61	240.86	409.09	240.86	9.56	44.63	75.80	44.63
	Total	131.26	632.80	1074.75	632.80	63.22	295.02	501.08	295.02	11.93	55.67	94.56	55.67
	E. Butte	103.36	482.33	819.20	482.03	46.17	215.45	365.92	215.45	8.51	39.72	67.45	39.72
1969	Lasauses	26.55	123.91	210.45	123.91	13.10	61.12	103.81	61.12	2.61	12.18	20.69	12.18
	Stateline	114.07	532.34	904.13	532.34	52.91	246.92	419.37	246.92	10.05	46.90	79.66	46.90
	Total	140.62	656.25	1111.58	656.25	66.01	308.04	523.18	308.04	12.66	59.08	100.35	59.08
	E. Butte	134.27	626.60	1064.32	626.60	50.69	236.55	401.76	236.55	11.77	54.92	93.28	54.92
1970	Lasauses	24.45	114.08	193.75	114.08	12.24	57.11	97.00	57.11	2.50	11.65	19.79	11.65
	Stateline	113.85	531.28	902.33	531.28	52.51	245.03	416.15	245.03	9.97	46.52	79.02	46.52
	Total	138.30	645.36	1096.08	645.36	64.75	302.14	513.15	302.14	12.47	58.17	98.81	58.17
	E. Butte	100.39	468.49	795.69	468.49	45.91	214.24	363.86	214.24	8.77	41.00	69.64	41.00
1971	Lasauses	16.68	77.84	132.21	77.84	8.36	39.03	66.30	39.03	1.70	7.94	13.49	7.94
	Stateline	68.33	318.86	541.55	318.86	32.57	151.98	258.12	151.98	5.95	27.76	47.15	27.76
	Total	85.01	396.70	673.76	396.70	40.93	191.01	324.42	191.01	7.65	35.70	60.64	35.70
	E. Butte	50.75	236.86	402.28	236.76	24.15	112.72	191.49	112.72	4.51	21.03	35.72	21.03
~% Annual Increase		↑ 4.5	↑ 21.0	↑ 53.5	↑ 21.0								

Weekly Distribution of Compact Deliveries

Flow Per Week (cfs)

Level of Treatment			100%					50%					10%			
Year	Location		1-2	3-4	5-7	8-9		1-2	3-4	5-7	8-9		1-2	3-4	5-7	8-9
1972	Lasauses		13.49	62.94	106.90	62.94		6.71	31.32	53.19	31.32		1.28	5.98	10.15	5.98
	Stateline		66.14	308.65	524.21	308.65		31.40	146.53	248.87	146.53		5.82	27.16	416.13	27.16
	Total		79.63	371.59	631.11	371.59		38.11	177.85	302.06	302.06		7.10	33.14	56.28	33.14
	E Butte		46.56	217.26	369.00	217.26		22.09	103.11	175.12	103.11		4.10	19.14	32.51	19.14
1973	Lasauses		29.49	123.84 / 151.36	5 / 210.34 / 6.7 / 215.40	137.60		14.69	61.69 / 35.39	116.40	68.54		2.03	9.96	16.06	9.46
	Stateline		199.78	859.06 / 1025.53	1583.41	932.29		93.57	436.64	741.60	436.64		16.02	74.74	126.94	74.74
	Total		229.27	1176.88 same	1793.75 / 1828.81	1069.89		108.26	498.33 / 512.03	858.00	505.18		18.05	84.20	143.00	84.20
	E. Butte		229.27	same	1797.75 / 1828.81	1069.89		108.26	498.33 / 512.03	858.00	505.18		18.04	84.20	143.00	84.20
1974	Lasauses		12.42	57.95	98.42	57.95		5.71	26.63	45.23	26.63		1.12	5.22	8.87	5.22
	Stateline		42.63	196.16	333.15	196.16		19.57	91.31	155.08	91.31		3.73	17.40	29.55	17.40
	Total		54.45	254.11	431.57	254.11		25.28	117.94	200.31	117.94		4.85	2262	38.42	22.62
	E. Butte		31.63	147.59	250.67	147.59		14.70	68.61	116.53	68.61		2.87	13.39	22.74	13.39
1975	Lasauses		28.71	123.93 / 147.79	228.18	134.35		14.41	60.53 / 33.98	114.22	67.25		2.92	12.36 / 14.98	23.13	13.62
	Stateline		193.39	902.49	1532.79	902.49		89.34	416.90	708.07	416.90		16.31	76.10	129.25	76.10
	Total		222.18	1033.41 / 1050.28	1760.97	1036.84		103.75	477.43 / 480.88	822.29	484.15		19.23	88.36 / 91.09	152.38	89.72
	E. Butte		215.32	1004.84	1706.63	1004.84		99.71	465.31	790.29	465.31		17.86	83.36	141.59	83.36

Weekly Distribution of Compact Delivery

Flow Per Week (cfs)

Level of Treatment		100%				50%				10%			
Year	Location	1-2	3-4	5-7	8-9	1-2	3-4	5-7	8-9	1-2	3-4	5-7	8-9
1976	Lasauses	18.17	84.80	144.03	84.80	9.06	42.29	71.82	42.29	1.77	8.25	14.00	8.25
	Stateline	81.12	378.54	642.93	378.54	37.87	176.71	300.13	176.71	7.00	32.68	55.50	32.68
	Total	99.29	463.34	786.96	463.34	46.93	219.00	371.95	219.06	8.77	40.93	69.50	40.93
	E. Butte	63.45	296.09	502.88	296.09	29.41	137.23	233.07	137.23	5.40	25.19	42.78	25.19
1977	Lasauses	7.55	35.25	59.87	35.25	2.61	12.18	20.69	12.18	0.00	0.00	0.00	0.00
	Stateline	31.38	146.46	248.74	146.46	12.50	58.32	99.06	58.32	1.86	8.70	14.78	8.70
	Total	38.93	181.71	308.61	181.71	15.11	70.50	119.75	70.50	1.86	8.70	14.78	8.70
	E. Butte	22.21	103.64	176.02	103.64	8.62	40.24	68.35	40.24	0.00	0.00	0.00	0.00
1978	Lasauses	17.99	83.97	142.62	83.97	8.96	41.83	71.05	41.83	1.73	8.09	13.75	8.09
	Stateline	57.60	268.78	456.50	268.78	27.31	127.47	216.49	127.47	5.37	25.04	42.53	25.04
	Total	75.59	352.75	599.12	352.75	36.27	169.30	287.54	169.30	7.10	33.13	56.28	33.13
	E. Butte	48.99	228.61	388.27	228.61	23.18	108.18	183.73	108.18	4.54	21.18	35.98	21.18
1979	Lasauses	30.80	143.73	244.13	143.73	15.43	72.02	122.32	72.02	3.14	14.68	24.93	14.68
	Stateline	252.82	1179.81	2003.81	1179.81	122.65	572.36	972.10	572.36	23.67	110.415	187.58	110.415
	Total	283.62	1323.54	2247.93	1323.54	138.08	644.38	1094.42	644.38	26.81	125.13	212.51	125.13
	E. Butte	283.62	1323.54	2247.93	1323.54	138.08	644.37	1094.41	644.37	26.81	125.12	212.51	125.12

Weekly Distribution of Compact Deliveries

Flow Per Week (cfs)

Level of Treatment		100%				50%				10%			
Year	Location	1-2	3-4	5-7	8-9	1-2	3-4	5-7	8-9	1-2	3-4	5-7	8-9
1980	Lasauses	25.29	106.21 / 129.81	200.43	118.01	12.61	56.50 / 61.20	99.96	58.85	2.48	11.11 / 12.03	19.66	11.57
	Stateline	139.20	649.59	1103.28	649.59	60.45	282.09	479.11	282.09	11.43	53.33	90.58	53.33
	Total	164.49	755.80 / 779.40	1303.71	767.60	73.06	338.59 / 343.29	579.07	340.94	13.91	64.44 / 65.36	110.24	64.90
	E. Butte	160.80	748.08 / 771.40	1290.35	759.74	72.30	337.39	573.03	337.39	13.73	64.07	108.82	64.07
1981	Lasauses	14.39	67.18	114.09	67.18	7.20	33.59	57.05	33.59	1.44	6.73	11.43	6.73
	Stateline	62.39	292.08	496.07	292.08	29.47	137.53	233.58	137.53	5.75	26.86	45.61	26.86
	Total	76.78	359.26	610.16	359.26	36.67	171.12	290.63	171.12	7.19	33.59	57.04	33.59
	E. Butte	44.66	208.41	353.97	208.41	21.27	99.25	168.57	99.25	4.18	19.52	33.15	19.52
1982	Lasauses	29.28	132.96 / 159.28	232.04	136.62	14.64	61.48 / 75.14	116.02	68.31	2.92	12.26 / 14.99	23.13	13.62
	Stateline	129.18	602.89	1023.87	602.89	57.77	269.61	457.91	269.61	11.64	51.52	87.50	51.52
	Total	158.46	735.85 / 753.12	1235.91	739.96	72.41	331.09 / 344.75	573.93	337.92	13.96	63.78 / 66.50	110.63	65.14
	E. Butte	152.56	711.93	1209.15	711.93	69.09	322.41	547.59	322.41	12.90	60.22	102.27	60.22

APPENDIX C

USDA REPORT

"VALUE OF SURFACE IRRIGATION WATER

IN THE SAN LUIS VALLEY"

by

DON ROSENTHAL

and

TOM BROWN

MAY 23, 1984

Value of Surface Irrigation Water in the San Luis Valley

by

Don Rosenthal

and

Tom Brown

May 23, 1984

Value of Surface Irrigation Water in the San Luis Valley

The purpose of this report is to document the procedure used for determining the value of surface irrigation water in the San Luis Valley. The major source of information found on water value in that area is a series of crop budgets completed by Johnson (1974). Before discussing those budgets, a comment on how increased water supplies will be used is needed.

All of the calculations reported here assume increased runoff will be used to irrigate additional acreage in the San Luis Valley. Another likely use for increased surface water is to flood fields early in the season to help replenish groundwater supplies. The chief benefit in this case is the reduction in pumping costs due to decreased lifting distances. This important point ought to be pursued. We agree that this reduction in pumping costs might be a very reasonable way to value increased flows early in the year. The question is, how will the water be used? Three people who might help sort this out are Richard Sparks (agronomist with the Soil Conservation Service, Alamosa, phone 303-589-6649), Ralph Curtis (head, Rio Grande Conservancy District, Alamosa, phone 303-589-6301), and Jim Shafer (Soil Conservation Service, Monte Vista, phone 303-852-5114). If the assumption of irrigating additional acreage is unreasonable, then the values reported here must be adjusted. Whether or not legal claims can be made to increased flows might be a factor in this increased acreage issue.

Definition of the Value of Irrigation Water

Young and Gray (1972) define "five distinct concepts of irrigation water value." The five concepts are: (1) the value of water to the farmer in (a) the very short run, (b) the short run, and (c) the long run; (2) the long run

regional value of water; and (3) the long run national value of water. As is typical in economic theory, length of run considerations pertain to which factors of production are considered fixed and which are variable. The shorter the run, the more fixed factors there are. The distinction between private, regional, and national value relates to the accounting stance used in cost-benefit calculations. A private accounting stance only includes cost and benefits to individual farmers whereas a national or regional accounting stance includes all of the former plus social cost and benefits. For agriculture, a major reason for the divergence between private and national values is the price support of many agricultural commodities.

A major purpose of the Rio Grande study is to determine how additional surface water will be used. Given that private farmers and individual water right holders will determine how additional water will be used (at least within the San Luis Valley), private values seem the logical value to use for modeling purposes. However, a national perspective is most appropriate for cost-benefit calculations by the U.S. Forest Service.

The selection of the length of run to use for modeling is less clear. Very short run values refer to within-season allocation decisions. In this situation the value of water would refer to the farmer's willingness to pay for water given that crops have been planted, fertilizer applied, etc. Clearly, willingness to pay under these circumstances can be quite high--up to the market value of the crops themselves. Because the additional water yields will be available year after year, this seems an inappropriate value to use. Short run values refer to how much water to apply over a crop season. In short run analysis the amount of land and the water distribution systems are assumed to be fixed. The short run marginal value of water is determined by how much crop yields can be increased with additional water supplies given

these fixed inputs. For this study it seems reasonable to allow for land acreage changes as a result of increased water supplies, and therefore, the short run value concept is not appropriate. The only choice left is the long run private value of water.

The long run value of water is defined as the change in net farm income associated with a specified increase in water supplies. All inputs are considered variable, including the land base. By now the reader will have ascertained that there is really a continuum of lengths of runs varying from the very short run to the very long run. The actual value which is to be reported is probably best described as a medium-long run value. A fairly long length of run seems most realistic for this study as the increased water supplies will likely be available for many years.

Method of Determining the Value of Water

The best data set that we could find for determining the value of water in the San Luis Valley was a series of crop budgets done by Johnson in 1974. The Johnson study appears to be very thorough and carefully done, though it is old. According to Norm Dalstead at the CSU Department of Agricultural and Natural Resource Economics, 1983 crop budgets for the San Luis Valley will be available in the Fall of 1984. It will be interesting to check these new budgets when they are available.

Given that Johnson 1974 crop budgets are all that is available, two factors remain: (1) to determine the long run private value of water in 1974; and (2) update these figures to 1984. For the San Luis Valley, the long-run value of water for any given crop can be approximated by:

$$V_w = \frac{p.q - (.05)p.q - Cost_v - Cost_{fo} - L}{W} \qquad (1)$$

where: V_w = value of an acre foot of water,

p = output price,

q = quantity of output produced,

$Cost_v$ = variable cost

$Cost_{fo}$ = out-of-pocket fixed cost,

L = amortized land development costs,

W = acre feet of water used.

Formula (1) was suggested by Bob Young at CSU as to approximate V_w. The rationale behind equation (1) is that new water will allow additional farm acreage, thereby increasing net income in the San Luis Valley.

The (.05)p.q term in equation (1) reflects a charge for the management and marketing services of the farm operators. The $Cost_{fo}$ term includes such items as insurance premiums, interest charges on the capital value of equipment, and depreciation, but excludes any opportunity cost for land. Non-irrigated land in the San Luis Valley is assumed to have a zero opportunity cost. The L term is included because starting new farms or irrigating additional acreage on existing farms involves such one time costs as leveling and clearing the land. This one time capital expense has to be converted to an annual cost (e.g., 4 percent of capital cost) to use equation (1).

To calculate V_w for this study, the L term was set equal to zero. This was done because good data on land clearing costs were not obtained. This is not an unreasonable assumption if fallow land is available within the Valley.

In order to update the Johnson (1974) data to 1985, two adjustments were necessary. First, a simple linear regression on commodity output prices from 1973 to 1982 was used to predict output prices in 1985. The commodity output price data is reported by the Colorado Department of Agriculture (1983). For barley the output price was obtained by contacting Adolph Coors Company. The results of these computations are reported in Table 1.

The second adjustment involves updating the input prices, i.e., $Cost_v$ and $Cost_{fo}$, to 1985. This was done by regressing the index of prices paid by farmers for production items on the gross national product implicit price deflator for the years 1973-1982. A projection of the level of the GNP index for 1985 by the Council of Economic Advisers was then used in the regression equation to predict the level of the farm index for 1985. These calculations are shown in Table 2. The 1985 predicted farm index number was then divided by the 1974 farm index and the resulting quotient, 2.15 (i.e., 178.44/83 = 2.15), was used as a multiplicative cost adjustment factor in updating the crop budgets to 1985.

The Table 1 and Table 2 information was then used to update the Johnson (1974) crop budgets to 1985. The results of these computations are displayed in Table 3. Only the surface irrigation budgets were updated because it is unlikely surface water will be used directly in sprinkler irrigation. The water values reported are based on equation (1). Where more than one value is shown for a single crop, a simple average of those values is probably sufficient. However, if the geographic breakdown of Johnson's work can be maintained during the modeling process, then separate values for individual subareas might be useful. Figure 1 shows the geographic location of the subareas.

The low figures for barley are unusual. Johnson (1974) points out that barley is much more efficiently grown with sprinkler irrigation than surface irrigation. Because sprinklers are generally run from groundwater, sprinkler irrigation values are not appropriate for this study. This points to the need to resolve the groundwater-surface water issue mentioned in the beginning of this report.

Notes

1) The Bureau of Reclamation is using a value of $28.70 for the value of water in their economic analysis of the Closed Basin Project. According to Adrian Hutchins with the Bureau, this is based upon updating 20 year old crop budgets. He was reluctant to share his specific numbers with me.

2) As mentioned earlier in this paper, it will be useful to look at the new 1983 San Luis Valley crop budgets once they become available in the Fall of 1984. In updating crop budgets over a 10 year period, we have assumed no technical change in the farms. The reasonableness of this assumption can be addressed by inspecting the new crop budgets.

3) The crop budgets apply only to the Closed Basin area within the San Luis Valley. Whether or not these values can be used for other areas in the San Luis Valley depends on the similarity of farming practices and yields within the Valley. Richard Sparks with the SCS would be an excellent person to speak to about this. In particular, if yields per acre outside the Closed Basin are significantly different then the Table 1 calculations can be redone accordingly.

4) Johnson provides 1984 crop acreages which were used to estimate the percentage of San Luis Valley acreage in different crops. Assuming that SRKs regions 1-5 occupy 25, 15, 10, 25, and 25 percent of the Valley, respectively, their current (1984) percentages by crops (Handout #4 of February 24 meeting) agree very closely with Johnson's 1974 percentages, indicating little change in cropping patterns during the past decade.

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Table 1

Updating Prices Reported in Colorado
Agricultural Statistics 1982

	Malt Barley (cwt.)[a]	Potatoes (cwt.)	Alfalfa (ton)	Other (Grass) Hay (ton)
1973	6.25	5.06[b]	44.25	46.55
1974	7.50	2.51	52.00	52.00
1975		3.81	54.10	53.80
1976		2.68	56.30	55.30
1977		2.88	54.90	56.30
1978		2.34	50.10	49.80
1979		2.91	53.30	52.30
1980	7.18	6.70	64.00	66.00
1981	7.68	4.70	64.50	66.00
1982	7.96	4.10	66.50	68.00
Pred. 1982	8.00	4.77	64.82	65.78
Pred. 1983	8.39	5.05	66.78	67.82
Pred. 1984	8.78	5.34	68.74	69.86
Pred. 1985	9.17	5.62	70.70	71.90
R^2	.97	.31	.71	.68
a	6.38	2.20	45.21	45.39
b	.39	.29	1.96	2.04

a Malt barley prices obtained from Adolph Coors Company. The regression for barley is based on only 1980, 1981, and 1982 prices. An inflation adjusted (1982 dollars) average of the 1980, 1981, and 1982 price yields an average price of $8.14. Updating this to 1985 dollars yields a predicted 1985 price of $9.28. The GNP deflator was used for all inflation adjustments.

b This data point not used in the potatoe regression.

Table 2

Updating Prices Paid by Farmers

	Prices Paid by Farmers Index: Production Items (1977 = 100)[a]	Gross National Product Implicit Price Deflator Index (1972 = 100)[b]
1973	73	105.75
1974	83	115.08
1975	91	125.79
1976	97	132.34
1977	100	140.05
1978	108	150.42
1979	125	163.42
1980	138	178.42
1981	148	195.14
1982	149	206.88
1983	162.33 (Pred.)[a]	215.63
1984	169.78 (Pred.)	225.00 (Pred.)[b]
1985	178.44 (Pred.)	235.90 (Pred.)

a Farm Index (Predicted) = -9.12 + .80 X GNP Index R^2 = .98

b GNP index predictions obtained from the Council of Economic Advisers.

c Farm index by U.S. Dept. of Agriculture (1983).

d GNP index reported by U.S. Department of Commerce.

Table 3

Updating Johnson's (1974) Crop Budgets

			1974						
Crop	Subarea	Yield	Price	Variable Cost	Out of Pocket Fixed[a]	1985 Price[b]	Acre Feet	1974 Value[c]	1985 Value[d]
Malt Barley	II	25.5	6.50	121.50	38.44	9.17	5	- .50	-24.35
Malt Barley	III	30.00	6.50	135.41	38.44	9.17	5	2.28	-22.49
Malt Barley	IV	35.00	6.50	137.80	38.56	9.17	5.28	7.53	-14.07
Malt Barley	V	30.00	6.50	127.82	40.38	9.17	5.23	3.26	-19.17
F :oes	III	255	3.00	379.48	54.36	5.62	3.60	81.36	119.08
Potatoes	IV	250	3.00	361.95	51.61	5.62	3.33	89.77	133.81
Alfalfa Hay	I, II	2.00	55.00	51.89	23.92	70.70	2.67	10.75	-10.73
Alfalfa Hay	V	2.25	55.00	51.89	23.92	70.70	2.67	15.64	-4.45
Grass Hay	I	1.50	48.00	35.18	22.15	71.90	2.40	4.61	-8.67

[a] This corresponds to overhead charges plus depreciation, taxes, and insurance on machinery and equipment plus an interest charge at 4 percent on machinery, equipment, and overhead (i.e., item 6 plus one-half of item 9 in Johnson's crop budgets). Unfortunately, taxes were not reported separately and, therefore, are incorrectly counted as a fixed cost.

[b] See Table 2

[c] 1974 Value = (1974 price x yield - .05 x 1974 price x yield - variable cost - fixed cost)/acre feet

[d] 1985 Value = (1985 price x yield - .05 x 1985 price x yield - 2.15 (variable cost + fixed cost)/acre feet

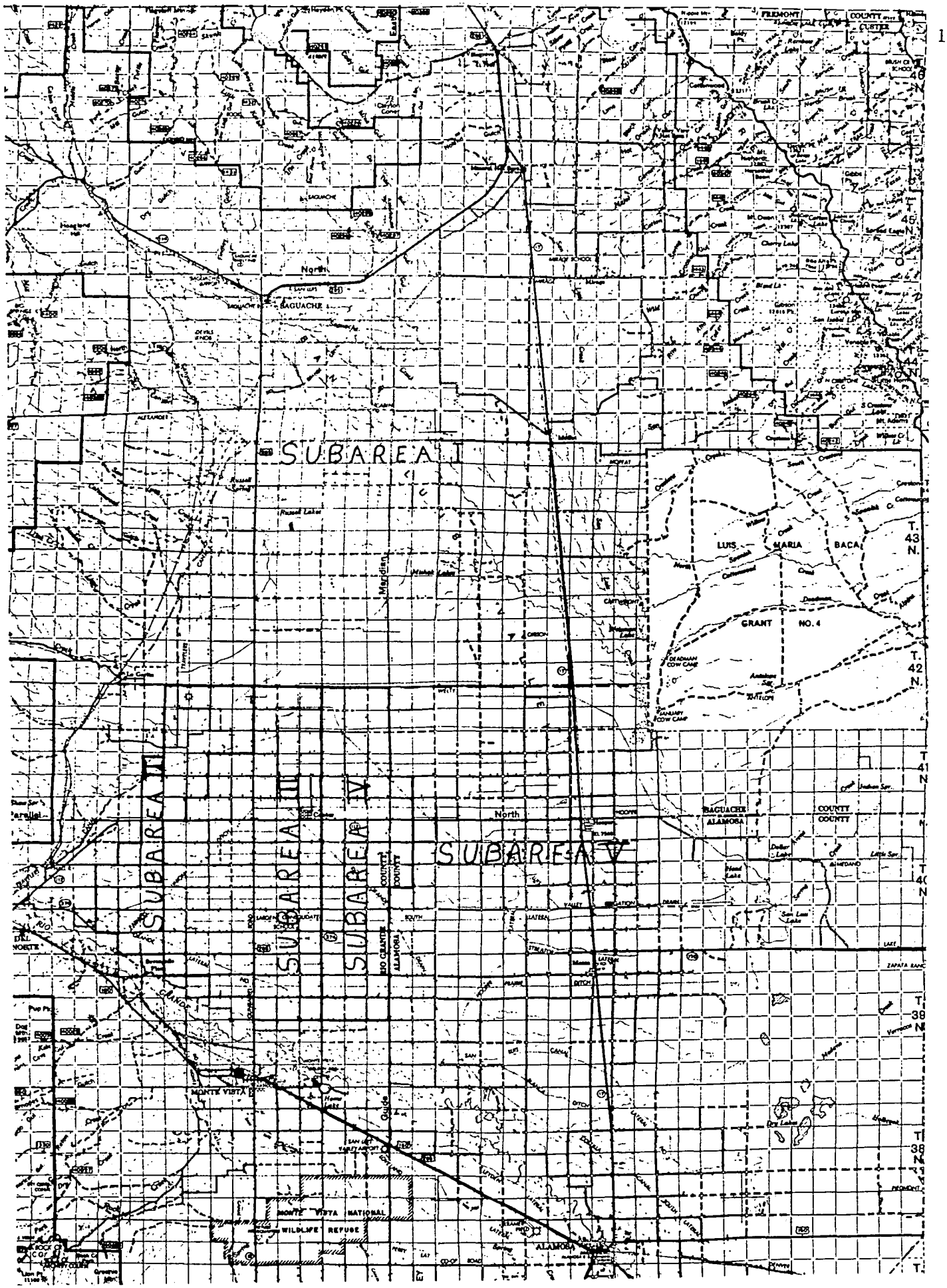

Figure 1

Location of Subareas

APPENDIX D
LISTING OF WATER RIGHTS ON THE RIO GRANDE AND CONEJOS RIVERS IN COLORADO

RIO GRANDE DATA BASE

SEQ#	NAME	APPRO DATE	AMT (CFS)	CUM (CFS)	REGION	GRSEQ#	SBSEQ#	GRCUM
1	SILVA D	3/12/1866	3.00	3.00	4	1	0	0.00
2	ATENCIO D	4/15/1866	.74	3.74	4	1	0	0.00
3	SAN JOSE D	4/30/1866	.90	4.64	4	1	0	0.00
4	SILVA D	5/31/1870	11.00	15.64	4	1	0	0.00
5	R G D #1	8/ 1/1870	12.80	28.44	4	1	1	28.44
6	MCDONALD D	5/ 1/1872	12.80	41.84	1	2	2	12.80
7	PRAIRIE D	5/ 1/1872	3.00	44.84	2	3	3	3.00
8	COCH/PION	6/ 9/1872	2.50	47.34	1	4	4	2.50
9	R G D #4	6/ 9/1872	1.20	48.54	4	5	0	0.00
10	HORN/YDREN	4/15/1873	2.20	50.74	4	5	0	0.00
11	DYER D	4/30/1873	1.00	51.74	4	5	5	4.40
12	MCDONALD D	5/31/1873	1.00	52.74	1	6	6	1.00
13	PACE D	5/31/1873	1.40	54.14	4	7	7	1.40
14	LOMA D	1/ 1/1874	2.00	56.14	1	8	8	2.00
15	BUTLER IRR	3/27/1874	1.00	57.14	2	9	0	0.00
16	BUTLER IRR	3/27/1874	1.00	58.14	2	9	0	0.00
17	HUBBARD D	3/27/1874	1.00	59.14	2	9	9	3.00
18	CENTENNIAL	4/20/1874	47.40	106.54	4	10	10	47.40
19	BILLINGS D	4/30/1874	1.50	108.04	2	11	0	0.00
20	FISH D	4/30/1874	1.50	109.54	2	11	11	3.00
21	KANE CA'N	5/ 1/1874	1.60	111.14	1	12	12	1.60
22	SILVA D	5/12/1874	2.80	113.94	4	13	0	0.00
23	ATENCIO D	5/31/1874	4.94	118.88	4	13	0	0.00
24	HORN/YDREN	5/31/1874	4.40	123.28	4	13	0	0.00
25	ANDERSON D	6/15/1874	2.90	126.18	4	13	0	0.00
26	ATKINS D	6/15/1874	.30	126.48	1	13	0	0.00
27	MEADOW OFL	9/20/1874	3.20	129.68	4	13	0	0.00
28	L,D,&B D	12/ 3/1874	1.80	131.48	4	13	13	20.34
29	ANNA RABER	3/31/1875	1.40	132.88	1	14	0	0.00
30	RABER D	3/31/1875	1.40	134.28	1	14	14	2.80
31	EXCELSIOR	4/ 1/1875	8.40	142.68	3	15	15	8.40
32	KANE CAL'N	5/ 1/1875	2.00	144.68	1	16	0	0.00
33	OFF D	5/ 1/1875	5.00	149.68	1	16	16	7.00
34	MCINTOSH	5/ 3/1875	2.80	152.48	4	17	17	2.80
35	R G D #2	5/ 3/1875	1.00	153.48	1	18	18	1.00
36	ANDERSON D	5/31/1875	11.33	164.81	4	19	19	11.33
37	ATKINS D	5/31/1875	.67	165.48	1	20	0	0.00
38	KANE CAL'N	6/ 7/1875	1.40	166.88	1	20	20	2.07
39	D NORTE TN	7/ 1/1876	5.00	171.88	4	21	0	0.00
40	D NORTE TN	7/ 1/1876	1.20	173.08	4	21	0	0.00
41	J PATR'SON	4/30/1877	3.60	176.68	4	21	0	0.00
42	HORN/YDREN	5/15/1877	5.00	181.68	4	21	0	0.00
43	ANDERSON D	5/31/1877	1.92	183.60	4	21	0	0.00
44	ATKINS D	5/31/1877	.08	183.68	1	21	0	0.00
45	ATENCIO D2	5/31/1877	4.00	187.68	4	21	0	0.00

46	SAN JOSE D	6/ 1/1877	1.00	188.68	4	21	0	0.00
47	R G PIEDRA	11/30/1877	42.90	231.58	4	21	0	0.00
48	R G S LUIS	6/ 1/1878	1.00	232.58	4	21	21	65.70
49	EXCELSIOR	9/30/1878	45.70	278.28	3	22	22	45.70
50	WESTSIDE D	12/31/1878	2.40	280.68	4	23	23	2.40
51	INDEPEND'T	3/24/1879	11.20	291.88	3	24	24	11.20
52	CENTENNIAL	6/23/1879	35.00	326.88	4	25	25	35.00
53	CHICAGO D	7/25/1879	23.20	350.08	3	26	26	23.20
54	HERMANITHAL	8/31/1879	2.80	352.88	1	27	0	0.00
55	R G CANAL	11/30/1879	11.20	364.08	1	27	0	0.00
56	S/SCHMIDT	12/30/1879	2.00	366.08	1	27	0	0.00
57	PARK GREEN	5/ 1/1880	1.00	367.08	1	27	0	0.00
58	SCHACHERAL	5/20/1880	1.00	368.08	1	27	27	18.00
59	NICHOL D	6/15/1880	8.00	376.08	4	28	0	0.00
60	ANDERSON D	9/15/1880	3.20	379.28	4	28	28	11.20
61	KANE CAL'N	12/31/1880	1.20	380.48	1	29	29	1.20
62	CHICAGO D	12/31/1880	3.20	383.68	3	30	30	3.20
63	BIEDEL.	12/31/1880	20.00	403.68	1	31	0	0.00
64	ENTERPRISE	1/ 1/1881	19.60	423.28	1	31	0	0.00
65	PARK GREEN	3/ 1/1881	2.20	425.48	1	31	0	0.00
66	R G D #2	3/ 1/1881	3.20	428.68	1	31	0	0.00
67	SCHACHERAL	4/ 1/1881	2.00	430.68	1	31	0	0.00
68	LOMA D	4/ 2/1881	2.90	433.58	1	31	31	49.90
69	R G S LUIS	4/ 2/1881	14.60	448.18	4	32	32	14.60
70	BILLINGS D	4/30/1881	7.80	455.98	2	33	0	0.00
71	FISH D	4/30/1881	7.80	463.78	2	33	33	15.60
72	L,D,&B D	5/ 1/1881	4.28	468.06	4	34	0	0.00
73	MCINTOSH	5/30/1881	1.20	469.26	4	34	34	5.48
74	R G CANAL	9/ 2/1881	318.40	787.66	1	35	35	318.40
75	R G LARIAT	10/13/1881	53.02	840.68	4	36	0	0.00
76	R G S LUIS	10/13/1881	.38	841.06	4	36	36	53.40
77	BUTLER IRR	4/ 5/1882	4.80	845.86	2	37	37	4.80
78	S/SCHMIDT	4/15/1882	1.60	847.46	1	38	38	1.60
79	HORN/YDREN	4/29/1882	1.10	848.56	4	39	0	0.00
80	R G S LUIS	4/29/1882	5.50	854.06	4	39	0	0.00
81	ATENCIO D	5/31/1882	.50	854.56	4	39	0	0.00
82	M VISTA	5/31/1882	132.20	986.76	4	39	0	0.00
83	MARAJO D	6/ 1/1882	.70	987.46	4	39	0	0.00
84	WESTSIDE D	6/30/1882	8.40	995.86	4	39	0	0.00
85	DUNNING ML	7/ 1/1882	.60	996.46	1	39	0	0.00
86	EMPIRE CNL	8/10/1882	312.30	1308.76	4	39	0	0.00
87	SILVA D	3/ 1/1883	1.40	1310.16	4	39	0	0.00
88	R G PIEDRA	4/ 1/1883	32.80	1342.96	4	39	0	0.00
89	MARAJO D	4/ 1/1883	1.20	1344.16	4	39	39	496.70
90	HALL-VOSS	4/ 1/1883	1.00	1345.16	1	40	40	1.00
91	SAN JOSE D	5/31/1883	3.50	1348.66	4	41	41	3.50
92	EXCELSIOR	5/31/1883	6.20	1354.86	3	42	42	6.20
93	SILVA D	6/10/1883	.80	1355.66	4	43	0	0.00
94	MEADOW OVF	12/31/1883	.80	1356.46	4	43	0	0.00
95	WESTSIDE D	4/ 1/1884	12.80	1369.26	4	43	43	14.40
96	EXCELSIOR	5/30/1884	29.40	1398.66	3	44	44	29.40
97	STAR D	5/30/1884	12.00	1410.66	4	45	45	12.00
98	SAN LUIS V	1/ 5/1885	92.90	1503.56	2	46	46	92.90
99	WESTSIDE D	4/ 1/1885	1.20	1504.76	4	47	47	1.20

100	HALL D	5/ 1/1885	.80	1505.56	1	48	0	0.00
101	R G CANAL	6/10/1885	22.80	1528.36	1	48	48	23.60
102	WESTSIDE D	4/ 1/1886	1.20	1529.56	4	49	0	0.00
103	R G D #4	6/ 1/1886	12.00	1541.56	4	49	49	13.20
104	R G CANAL	6/10/1886	22.70	1564.26	1	50	0	0.00
105	KANE CAL'N	6/30/1886	2.00	1566.26	1	50	50	24.70
106	COSTILLA	8/11/1886	103.30	1669.56	3	51	51	103.30
107	PRAIRIE D	2/ 9/1887	105.10	1774.66	2	52	52	105.10
108	R G S LUIS	3/21/1887	9.52	1784.18	4	53	0	0.00
109	STAR ENLT	3/21/1887	.48	1784.66	4	53	0	0.00
110	WESTSIDE D	4/ 1/1887	1.20	1785.86	4	53	53	11.20
111	BILLINGS D	4/ 1/1887	16.70	1802.56	2	54	0	0.00
112	FARMERS UN	4/ 1/1887	.25	1802.81	1	54	0	0.00
113	PRAIRIE D	4/ 1/1887	.75	1803.56	2	54	54	17.70
114	EMPIRE CNL	5/16/1887	6.00	1809.56	4	55	55	6.00
115	R G CANAL	6/10/1887	26.00	1835.56	1	56	0	0.00
116	PARK GREEN	7/ 1/1887	2.00	1837.56	1	56	0	0.00
117	FARMERS UN	11/ 9/1887	138.80	1976.36	1	56	0	0.00
118	S/SCHMIDT	3/ 1/1888	.80	1977.16	1	56	56	167.60
119	WESTSIDE D	4/ 1/1888	1.20	1978.36	4	57	57	1.20
120	BILLINGS D	4/ 1/1888	4.44	1982.80	2	58	0	0.00
121	FARMERS UN	4/ 1/1888	.25	1983.05	1	58	0	0.00
122	PRAIRIE D	4/ 1/1888	.75	1983.80	2	58	58	5.44
123	EMPIRE CNL	5/16/1888	2.30	1986.10	4	59	59	2.30
124	R G CANAL	6/10/1888	33.60	2019.70	1	60	0	0.00
125	BREY D	8/ 1/1888	1.00	2020.70	1	60	0	0.00
126	R G CANAL	3/30/1889	24.40	2045.10	1	60	60	59.00
127	MARAJO D	4/ 1/1889	3.10	2048.20	4	61	0	0.00
128	WESTSIDE D	4/ 1/1889	1.40	2049.60	4	61	61	4.50
129	BILLINGS D	4/ 1/1889	4.50	2054.10	2	62	62	4.50
130	HALL-VOSS	4/ 1/1889	.15	2054.25	1	63	0	0.00
131	FARMERS UN	4/ 1/1889	.95	2055.20	1	63	63	1.10
132	PRAIRIE D	4/ 1/1889	2.85	2058.05	2	64	0	0.00
133	KENILWORTH	4/ 1/1889	.70	2058.75	2	64	64	3.55
134	M VISTA C	5/24/1889	125.30	2184.05	4	65	65	125.30
135	R G CANAL	6/10/1889	16.60	2200.65	1	66	66	16.60
136	EMPIRE CNL	10/30/1889	92.00	2292.65	4	67	0	0.00
137	EMPIRE CNL	1/31/1890	93.32	2385.97	4	67	67	185.32
138	KENILWORTH	4/ 1/1890	3.40	2389.37	2	68	68	3.40
139	WESTSIDE D	5/31/1890	6.00	2395.37	4	69	69	6.00
140	R G CANAL	6/10/1890	43.40	2438.77	1	70	0	0.00
141	R G CANAL	7/24/1890	52.00	2490.77	1	70	70	95.40
142	EMPIRE CNL	8/ 4/1890	29.00	2519.77	4	71	71	29.00
143	R G CANAL	11/17/1891	293.70	2813.47	1	72	0	0.00
144	BREY D	7/ 1/1874	3.80	2817.27	1	72	0	0.00
145	ALDRICH D	6/15/1884	.80	2818.07	4	72	0	0.00
146	SLOUGH D	5/ 1/1889	2.00	2820.07	1	72	0	0.00
147	ANNA RABR	5/ 1/1887	2.40	2822.47	1	72	0	0.00
148	RABER D	6/30/1887	2.40	2824.87	1	72	72	305.10
149	R G LARIAT	6/30/1887	2.61	2827.48	4	73	0	0.00
150	R G LARIAT	6/30/1889	3.62	2831.10	4	73	73	6.23
151	PRAIRIE D	6/30/1889	11.07	2842.17	2	74	74	11.07
152	FARMERS UN	6/30/1889	5.45	2847.62	1	75	0	0.00
153	SOUTHEY D1	6/30/1889	.70	2848.32	2	75	75	6.15

154	NEW DITCH	6/30/1890	2.61	2850.93	3	76	76	2.61
155	R G LARIAT	6/30/1890	5.86	2856.79	4	77	77	5.86
156	SAN LUIS V	6/30/1890	161.46	3018.25	2	78	0	0.00
157	PRAIRIE D	6/30/1890	36.84	3055.09	2	78	78	198.30
158	R G S LUIS	6/30/1890	19.06	3074.15	4	79	0	0.00
159	STAR D	6/30/1890	.96	3075.11	4	79	79	20.02
160	FARMERS UN	6/30/1890	105.41	3180.52	1	80	80	105.41
161	BLANCA CNL	6/30/1890	5.21	3185.73	2	81	0	0.00
162	SOUTHEY D1	6/30/1890	1.30	3187.03	2	81	81	6.51
163	R G PIEDRA	6/30/1891	.38	3187.41	4	82	0	0.00
164	M VISTA C	6/30/1891	13.35	3200.76	4	82	0	0.00
165	R G LARIAT	6/30/1891	15.87	3216.63	4	82	82	29.60
166	R G CANAL	6/30/1891	45.00	3261.63	1	83	83	45.00
167	SAN LUIS V	6/30/1891	44.27	3305.90	2	84	0	0.00
168	PRAIRIE D	6/30/1891	59.90	3365.80	2	84	84	104.17
169	FARMERS UN	6/30/1891	280.47	3646.27	1	85	85	280.47
170	BLANCA CNL	6/30/1891	11.07	3657.34	2	86	86	11.07
171	R G PIEDRA	6/30/1892	.85	3658.19	4	87	0	0.00
172	M VISTA C	6/30/1892	20.58	3678.77	4	87	0	0.00
173	R G LARIAT	6/30/1892	2.28	3681.05	4	87	87	23.71
174	R G CANAL	6/30/1892	84.96	3766.01	1	88	88	84.96
175	PRAIRIE D	6/30/1892	20.18	3786.19	2	89	0	0.00
176	R G S LUIS	6/30/1892	.54	3786.73	4	89	0	0.00
177	STAR D	6/30/1892	.03	3786.76	4	89	89	20.75
178	FARMERS UN	6/30/1892	159.69	3946.45	1	90	90	159.69
179	R G PIEDRA	6/30/1893	1.14	3947.59	4	91	0	0.00
180	M VISTA C	6/30/1893	9.44	3957.03	4	91	0	0.00
181	R G LARIAT	6/30/1893	10.42	3967.45	4	91	91	21.00
182	R G CANAL	6/30/1893	48.99	4016.44	1	92	92	48.99
183	SAN LUIS V	6/30/1893	31.25	4047.69	2	93	0	0.00
184	PRAIRIE D	6/30/1893	22.79	4070.48	2	93	93	54.04
185	R G S LUIS	6/30/1893	2.48	4072.96	4	94	0	0.00
186	STAR D	6/30/1893	.13	4073.09	4	94	0	0.00
187	FARMERS UN	6/30/1893	110.18	4183.27	4	94	94	112.79
188	BLANCA CNL	6/30/1893	15.63	4198.90	2	95	95	15.63
189	M VISTA C	6/30/1894	3.75	4202.65	4	96	0	0.00
190	R G LARIAT	6/30/1894	3.91	4206.56	4	96	96	7.66
191	R G CANAL	6/30/1894	38.74	4245.30	1	97	97	38.74
192	SAN LUIS V	6/30/1894	10.42	4255.72	2	98	0	0.00
193	PRAIRIE D	6/30/1894	20.84	4276.56	2	98	0	0.00
194	BLANCA CNL	6/30/1894	13.02	4289.58	2	98	0	0.00
195	CARP LK D	6/30/1894	1.00	4290.58	2	98	98	45.28
196	M VISTA C	6/30/1895	1.63	4292.21	4	99	0	0.00
197	R G LARIAT	6/30/1895	2.04	4294.25	4	99	99	3.67
198	R G CANAL	6/30/1895	41.34	4335.59	1	100	100	41.34
199	SAN LUIS V	6/30/1895	7.81	4343.40	2	101	0	0.00
200	PRAIRIE D	6/30/1895	24.74	4368.14	2	101	0	0.00
201	SOUTHEY #1	6/30/1895	.50	4368.64	2	101	101	33.05
202	R G D #4E	6/30/1895	1.20	4369.84	4	102	102	1.20
203	WEISS D	5/15/1896	1.34	4371.18	1	103	103	1.34
204	R G PIEDRA	6/30/1896	1.91	4373.09	4	104	0	0.00
205	M VISTA C	6/30/1896	10.42	4383.51	4	104	0	0.00
206	R G LARIAT	6/30/1896	3.26	4386.77	4	104	104	15.59
207	R G CANAL	6/30/1896	88.14	4474.91	1	105	105	88.14

208	SAN LUIS V	6/30/1896	18.23	4493.14	2	106	0	0.00
209	PRAIRIE D	6/30/1896	16.20	4509.34	2	106	0	0.00
210	BLANCA CNL	6/30/1896	14.33	4523.67	2	106	106	48.76
211	R G PIEDRA	6/30/1897	.57	4524.24	4	107	0	0.00
212	M VISTA C	6/30/1897	5.21	4529.45	4	107	0	0.00
213	R G LARIAT	6/30/1897	.65	4530.10	4	107	107	6.43
214	R G CANAL	6/30/1897	81.71	4611.81	1	108	108	81.71
215	SAN LUIS V	6/30/1897	20.84	4632.65	2	109	0	0.00
216	PRAIRIE D	6/30/1897	15.63	4648.28	2	109	109	36.47
217	R G PIEDRA	6/30/1898	3.00	4651.28	4	110	110	3.00
218	NEW D	6/30/1898	2.61	4653.89	3	111	111	2.61
219	M VISTA C	6/30/1898	14.33	4668.22	4	112	0	0.00
220	R G LARIAT	6/30/1898	2.61	4670.83	4	112	112	16.94
221	R G CANAL	6/30/1898	183.60	4854.43	1	113	113	183.60
222	SAN LUIS V	6/30/1898	26.04	4880.47	4	114	114	26.04
223	PRAIRIE D	6/30/1898	10.42	4890.89	2	115	0	0.00
224	BLANCA CNL	6/30/1898	10.42	4901.31	2	115	115	20.84
225	FISHBACK D	6/30/1898	.90	4902.21	4	116	0	0.00
226	ZINZER #2	3/15/1899	.80	4903.01	4	116	0	0.00
227	R G PIEDRA	6/30/1899	3.05	4906.06	4	116	0	0.00
228	M VISTA C	6/30/1899	4.56	4910.62	4	116	0	0.00
229	R G LARIAT	6/30/1899	.65	4911.27	4	116	116	9.96
230	R G CANAL	6/30/1899	82.68	4993.95	1	117	117	82.68
231	SAN LUIS V	6/30/1899	10.42	5004.37	2	118	0	0.00
232	PRAIRIE D	6/30/1899	6.51	5010.88	2	118	118	16.93
233	FISHBACK D	5/15/1900	1.00	5011.88	4	119	0	0.00
234	R G PIEDRA	6/30/1900	4.46	5016.34	4	119	119	5.46
235	R G CANAL	6/30/1900	44.92	5061.26	1	120	120	44.92
236	SAN LUIS V	6/30/1900	27.34	5088.60	2	121	0	0.00
237	PRAIRIE D	6/30/1900	6.84	5095.44	2	121	121	34.18
238	R G S LUIS	6/30/1900	.16	5095.60	4	122	0	0.00
239	STAR D	6/30/1900	.01	5095.61	4	122	0	0.00
240	ZINZER #2	6/30/1900	1.60	5097.21	4	122	0	0.00
241	SHOUP D	11/ 1/1900	.50	5097.71	4	122	0	0.00
242	R G PIEDRA	6/30/1901	3.42	5101.13	4	122	122	5.69
243	R G CANAL	6/30/1901	43.62	5144.75	1	123	123	43.62
244	PRAIRIE D	6/30/1901	2.61	5147.36	2	124	0	0.00
245	SOUTHEY #1	6/30/1901	.50	5147.86	2	124	124	3.11
246	ZINZER #2	6/30/1901	.60	5148.46	4	125	0	0.00
247	HECKER D	6/30/1901	3.20	5151.66	4	125	125	3.80
248	NEW D	6/30/1902	5.21	5156.87	3	126	126	5.21
249	R G D #4	12/31/1886	10.00	5166.87	4	127	127	10.00
250	MIDLAND D	8/31/1887	10.00	5176.87	1	128	128	10.00
251	DYER D	12/31/1890	3.00	5179.87	4	129	129	3.00
252	MINOR D	7/31/1896	2.00	5181.87	3	130	0	0.00
253	EHROWITZ D	4/15/1898	2.00	5183.87	3	130	0	0.00
254	EHROWITZ D	12/31/1901	4.00	5187.87	3	130	130	8.00
255	RG RESV	6/ 3/1903	2574.00	7761.87	**	131	0	0.00
256	RG RESV	6/ 3/1903	728.00	8489.87	**	131	131	3302.00
257	EHROWITZ	12/31/1907	3.00	8492.87	3	132	0	0.00
258	MINOR D	4/30/1909	3.00	8495.87	3	132	132	6.00
259	MOORE D	12/23/1909	6.00	8501.87	4	133	133	6.00
260	MIDLAND D	12/31/1911	50.00	8551.87	1	134	0	0.00
261	SONDLES D	6/19/1912	2.00	8553.87	1	134	134	52.00

262	INDEPEND'T	5/26/1889	45.00	8598.87	3	135	0	0.00
263	ADAMS #1	12/20/1900	3.00	8601.87	3	135	0	0.00
264	ADAMS #2	12/20/1900	3.00	8604.87	3	135	135	51.00
265	RG RESV	6/ 1/1903	380.40	8985.27	**	136	136	380.40
266	KANE CAL'N	4/ 1/1917	15.80	9001.07	1	137	137	15.80
267	MINOR D	9/16/1918	9.50	9010.57	3	138	0	0.00
268	MINOR D	4/20/1920	8.00	9018.57	3	138	0	0.00
269	CHICAGO D	4/20/1924	40.00	9058.57	3	138	138	57.50
270	DIEHL D	4/ 2/1928	4.50	9063.07	2	139	139	4.50
271	MEADOW OFL	5/25/1926	63.00	9126.07	4	140	140	63.00
272	NEW D	5/15/1936	20.00	9146.07	3	141	0	0.00
273	STANLEY KN	7/ 1/1951	6.00	9152.07	3	141	0	0.00
274	STEWART D	12/31/1951	20.00	9172.07	3	141	141	46.00
275	ARTIFICIAL	10/30/1957	0.00	9172.07	1	142	142	0.00
276	ARTIFICIAL	10/30/1957	0.00	9172.07	1	143	143	0.00
277	ARTIFICIAL	10/30/1957	0.00	9172.07	1	144	144	0.00
278	ARTIFICIAL	10/30/1957	0.00	9172.07	1	145	145	0.00
279	ARTIFICIAL	10/30/1957	0.00	9172.07	1	146	146	0.00
280	ARTIFICIAL	10/30/1957	0.00	9172.07	1	147	147	0.00
281	ARTIFICIAL	10/30/1957	0.00	9172.07	1	148	148	0.00
282	ARTIFICIAL	10/30/1957	0.00	9172.07	1	149	149	0.00
283	ARTIFICIAL	10/30/1957	0.00	9172.07	1	150	150	0.00
284	ARTIFICIAL	10/30/1957	0.00	9172.07	1	151	151	0.00
285	ARTIFICIAL	10/30/1957	0.00	9172.07	1	152	152	0.00
286	ARTIFICIAL	10/30/1957	0.00	9172.07	1	153	153	0.00
287	ARTIFICIAL	10/30/1957	0.00	9172.07	1	154	154	0.00
288	ARTIFICIAL	10/30/1957	0.00	9172.07	1	155	155	0.00
289	ARTIFICIAL	10/30/1957	0.00	9172.07	1	156	156	0.00
290	ARTIFICIAL	10/30/1957	0.00	9172.07	1	157	157	0.00

CONEJOS DATA BASE

SEQ#	NAME	APPRO DATE	AMT (CFS)	CUM (CFS)	REGION	GRSEQ#	SBSEQ#	GRCUM
1	G'LUPE MN.	3/ 1/1855	13.46	13.46	5	1	0	0.00
2	MANASSA #3	3/ 1/1855	29.79	43.25	5	1	0	0.00
3	ROMERO D	3/ 1/1855	26.57	69.82	5	1	0	0.00
4	HD'S ML&IR	6/ 1/1855	45.00	114.82	5	1	0	0.00
5	MANASSA 3#	6/ 1/1855	11.00	125.82	5	1	0	0.00
6	EL CODA D	8/ 4/1855	25.18	151.00	5	1	0	0.00
7	LLANO D	8/20/1855	31.18	182.18	5	1	0	0.00
8	GARCIA D-R	10/ 1/1855	6.23	188.41	5	1	0	0.00
9	MANASSA #3	3/ 5/1856	8.20	196.61	5	1	0	0.00
10	SERVIETTA	3/ 5/1856	23.57	220.18	5	1	1	220.18
11	SELEDONIA	3/20/1856	31.77	251.95	5	2	0	0.00
12	SALAZAR D	4/ 1/1856	12.32	264.27	5	2	0	0.00
13	MILL D	4/ 1/1856	12.67	276.94	5	2	0	0.00
14	SAN JOSE	4/15/1856	40.28	317.22	5	2	0	0.00
15	PUERTICITO	4/30/1856	8.76	325.98	5	2	0	0.00
16	SAN RAFAEL	5/ 1/1856	8.81	334.79	5	2	0	0.00
17	EL SERRITO	5/30/1856	6.19	340.98	5	2	0	0.00
18	G MARTINEZ	8/ 1/1856	3.71	344.69	5	2	0	0.00
19	GARCIA D-R	4/ 1/1857	6.09	350.78	5	2	0	0.00
20	MANASSA #3	4/ 1/1857	13.90	364.68	5	2	2	144.50
21	SANTIAGO D	4/ 1/1857	41.69	406.37	5	3	0	0.00
22	AR TROG #1	4/ 1/1857	8.81	415.18	5	3	0	0.00
23	OVERFLOW D	4/10/1857	11.79	426.97	5	3	0	0.00
24	TROGILLIO	4/15/1857	29.80	456.77	5	3	0	0.00
25	CANON IRR	4/15/1857	42.89	499.66	5	3	0	0.00
26	LA DEL RIO	4/30/1857	20.01	519.67	5	3	0	0.00
27	ROMERO D	4/30/1857	11.43	531.10	5	3	0	0.00
28	FUERTICITO	4/ 1/1858	31.47	562.57	5	3	0	0.00
29	MECITOS D	9/ 1/1858	38.99	601.56	5	3	0	0.00
30	S'JN/S'RAF	4/ 1/1861	47.76	649.32	5	3	3	284.64
31	SAN RAFAEL	4/ 1/1862	8.81	658.13	5	4	0	0.00
32	CHACON #1	5/ 1/1863	18.31	676.44	5	4	0	0.00
33	LOS SAUCES	5/20/1867	88.43	764.87	5	4	0	0.00
34	ROMERO D	3/ 1/1870	25.00	789.87	5	4	0	0.00
35	BR' ROMERO	3/15/1870	9.26	799.13	5	4	0	0.00
36	A D ARCH'A	8/20/1870	1.00	800.13	5	4	0	0.00
37	SANCHES D	8/20/1870	26.26	826.39	5	4	0	0.00
38	CHACON #3	7/ 1/1872	18.31	844.70	5	4	0	0.00
39	SABINE SCH	5/ 1/1873	11.95	856.65	5	4	0	0.00
40	VEGA G&SAB	4/ 1/1875	2.89	859.54	5	4	4	210.22
41	VEGA GRAND	4/ 1/1875	2.88	862.42	5	5	0	0.00
42	AN CON IRR	4/ 1/1876	10.80	873.22	5	5	0	0.00
43	W STEWART	6/30/1876	11.40	884.62	5	5	0	0.00
44	CHACON #2	10/15/1877	7.54	892.16	5	5	0	0.00

45	VEGA G&SAB	4/ 1/1878	2.88	895.04	5	5	0	0.00
46	VEGA GRAND	4/ 1/1878	2.89	897.93	5	5	0	0.00
47	MC CARROL	5/ 1/1878	13.72	911.65	5	5	0	0.00
48	MANASSA D	5/ 1/1879	38.60	950.25	5	5	0	0.00
49	MANASSA #3	5/ 1/1879	35.00	985.25	5	5	0	0.00
50	CHACON #2E	10/15/1879	4.54	989.79	5	5	5	130.25
51	W SABINE 1	4/ 1/1880	7.71	997.50	5	6	0	0.00
52	LOPEZ D	4/ 1/1880	2.88	1000.38	5	6	0	0.00
53	M'TINEZ 51	4/ 1/1880	12.96	1013.34	5	6	0	0.00
54	CORDOVA D	4/ 1/1880	6.54	1019.88	5	6	0	0.00
55	JACK'S IRR	3/25/1881	8.12	1028.00	5	6	0	0.00
56	EPHRAIM D	3/28/1881	47.00	1075.00	5	6	0	0.00
57	LOS OJOS 2	5/ 1/1881	5.95	1080.95	5	6	0	0.00
58	RICHFIELD	10/12/1881	56.24	1137.19	5	6	0	0.00
59	A D ARCH	2/15/1882	10.31	1147.50	5	6	0	0.00
60	AR TROG #1	4/15/1882	3.77	1151.27	5	6	6	161.48
61	BELCROFT	4/15/1882	3.77	1155.04	5	7	0	0.00
62	VEGA G&SAB	5/ 1/1882	7.71	1162.75	5	7	0	0.00
63	LOS OJOS 1	7/10/1882	40.08	1202.83	5	7	0	0.00
64	LOS OJOS 2	7/10/1882	4.08	1206.91	5	7	0	0.00
65	ELLEDGES D	4/ 1/1883	7.52	1214.43	5	7	0	0.00
66	ANGUSTURA	4/ 1/1883	26.00	1240.43	5	7	0	0.00
67	N'EASTERN	4/21/1883	34.71	1275.14	5	7	0	0.00
68	SAN RAFAEL	4/21/1883	4.00	1279.14	5	7	0	0.00
69	VEGA D	4/21/1883	6.40	1285.54	5	7	0	0.00
70	LE DUC D	4/21/1883	3.00	1288.54	5	7	7	137.27
71	HOME D	4/21/1883	4.50	1293.04	5	8	0	0.00
72	HALL BROS	4/21/1883	22.00	1315.04	5	8	0	0.00
73	HALL B'S 2	4/21/1883	20.00	1335.04	5	8	0	0.00
74	MANASSA #2	4/21/1883	23.25	1358.29	5	8	0	0.00
75	EAST BEND	4/21/1883	12.00	1370.29	5	8	0	0.00
76	E BEND #2	4/21/1883	3.00	1373.29	5	8	0	0.00
77	SMITH B'S	4/21/1883	8.00	1381.29	5	8	0	0.00
78	VEGA D	4/21/1883	2.00	1383.29	5	8	0	0.00
79	COTTONW'D	4/10/1884	28.50	1411.79	5	8	0	0.00
80	A D ARCH	4/20/1884	8.00	1419.79	5	8	8	131.25
81	CHACON #2E	5/ 1/1884	2.00	1421.79	5	9	0	0.00
82	MAN/W'FLD	2/15/1885	30.00	1451.79	5	9	0	0.00
83	BAGWELL D	3/13/1885	7.00	1458.79	5	9	0	0.00
84	AN CON D	4/23/1885	8.00	1466.79	5	9	0	0.00
85	E BEND #1E	5/30/1885	4.00	1470.79	5	9	0	0.00
86	E BEND #2E	8/31/1885	1.75	1472.54	5	9	0	0.00
87	E BEND #2	8/31/1885	2.00	1474.54	5	9	0	0.00
88	SANFORD D	10/20/1885	107.50	1582.04	5	9	0	0.00
89	RICHFIELD	10/20/1885	62.00	1644.04	5	9	0	0.00
90	VEGA D	1/ 1/1886	3.00	1647.04	5	9	9	227.25
91	ALAMO D	4/15/1886	36.00	1683.04	5	10	0	0.00
92	E BEND #3E	8/31/1886	3.65	1686.69	5	10	0	0.00
93	E BEND #4E	1/26/1887	1.00	1687.69	5	10	0	0.00
94	E BEND #2	1/26/1887	3.00	1690.69	5	10	0	0.00
95	SERVIETTA	4/ 1/1887	4.00	1694.69	5	10	0	0.00
96	MAN/W'FLD	4/11/1887	24.00	1718.69	5	10	0	0.00
97	ANTONITO	4/25/1887	139.00	1857.69	5	10	0	0.00
98	MAGOTE D	6/ 2/1887	342.40	2200.09	5	10	0	0.00

99	N'EASTERN	10/21/1887	41.25	2241.34	5	10	0	0.00
100	BRANCH D	11/ 1/1887	10.40	2251.74	5	10	10	604.70
101	W JACKSON	11/ 1/1887	1.60	2253.34	5	11	0	0.00
102	PAINE D #1	2/11/1888	1.50	2254.84	5	11	0	0.00
103	PAINE D #2	2/11/1888	4.00	2258.84	5	11	0	0.00
104	N'EASTERN	3/20/1888	16.84	2275.68	5	11	0	0.00
105	SERVIETTA	4/ 1/1888	4.00	2279.68	5	11	0	0.00
106	CARP/REEKR	4/ 5/1888	16.00	2295.68	5	11	0	0.00
107	STOVER D	4/20/1888	2.50	2298.18	5	11	0	0.00
108	MOGALES V	6/30/1888	12.00	2310.18	5	11	0	0.00
109	ROMERO D	10/ 3/1888	25.00	2335.18	5	11	0	0.00
110	BRAZO D'NT	3/25/1889	20.00	2355.18	5	11	11	103.44
111	LE DUC #1E	5/ 1/1889	2.00	2357.18	5	12	0	0.00
112	CHACON #2E	5/15/1889	2.00	2359.18	5	12	0	0.00
113	S JN/S RAF	7/20/1889	4.00	2363.18	5	12	0	0.00
114	LE DUC #2E	8/31/1889	1.00	2364.18	5	12	0	0.00
115	JACOBS #2	9/ 1/1889	1.00	2365.18	5	12	0	0.00
116	JACOBS #3	9/ 1/1889	2.00	2367.18	5	12	0	0.00
117	VANCE SPG	9/30/1890	3.00	2370.18	5	12	0	0.00
118	MAN/W'FLD	11/30/1892	170.50	2540.68	5	12	0	0.00
119	STOVER D	4/15/1893	2.00	2542.68	5	12	0	0.00
120	EL SERRITO	10/ 1/1893	10.00	2552.68	5	12	12	197.50
121	ROMERO D	4/17/1899	77.00	2629.68	5	13	0	0.00
122	MANASSA #3	2/12/1901	127.35	2757.03	5	13	0	0.00
123	NEW ROMERO	11/17/1901	17.82	2774.85	5	13	0	0.00
124	MANASSA #3	3/ 1/1902	148.47	2923.32	5	13	0	0.00
125	SANFORD D	3/10/1902	38.80	2962.12	5	13	0	0.00
126	SAN RAFAEL	4/20/1908	41.59	3003.71	5	13	0	0.00
127	OSIER D	10/10/1908	2.20	3005.91	5	13	0	0.00
128	BOSQUE IRR	4/17/1913	3.00	3008.91	5	13	0	0.00
129	CHRISTEN'N	4/18/1913	12.25	3021.16	5	13	0	0.00
130	TN ANTON'O	12/ 6/1939	.60	3021.76	5	13	13	469.08
131	ARTIFICIAL	10/30/1957	0.00	3021.76	5	14	14	0.00
132	ARTIFICIAL	10/30/1957	0.00	3021.76	5	15	15	0.00
133	ARTIFICIAL	10/30/1957	0.00	3021.76	5	16	16	0.00
134	ARTIFICIAL	10/30/1957	0.00	3021.76	5	17	17	0.00
135	ARTIFICIAL	10/30/1957	0.00	3021.76	5	18	18	0.00
136	ARTIFICIAL	10/30/1957	0.00	3021.76	5	19	19	0.00

APPENDIX E

CROP BUDGETS OBTAINED FROM

ST. LUIS VALLEY FARMERS RANCH MANAGEMENT ASSOCIATION

1983 ACRE COSTS FOR SELECTED CROPS

Operating Costs	POTATOES	BARLEY	WHEAT	HAY
Fertilizer	$ 86	$ 39	$ 47	$ 0
Chemicals	35	13	10	0
Seed-Storage-Other Crop Costs	129	22	12	5
Utilities	9	5	4	4
Machine Repair	75	28	22	21
Machine Hire	14	33	38	14
Fuel-Oil	34	20	15	11
Irrigation	51	46	52	25
Auto	1	1	1	1
Interest	108	60	55	36
Labor	62	23	23	10
Building Repair	2	3	1	0
Insurance	12	9	9	3
Taxes	20	17	12	4
Miscellaneous	8	6	5	5
Cash Rent-L.L. Costs	49	18	44	5
Total Cash	$ 695	$ 343	$ 350	$ 144
Plus: Estimated Costs For:				
Machinery Depreciation	$ 70	$ 11	$ 11	$ 11
Building Depreciation	25	4	4	4
Total	$ 790	$ 358	$ 365	$ 159

*ESTIMATED RANGE OF COSTS PER ACRE FOR SELECTED CROPS OF 1982

Variable Costs	Potatoes	Grain Crops	Alfalfa Hay	Grass Hay
Fertilizer	$ 70-125	$ 35-50	$ 0-25	$ 0-19
Seed	150-260	9-13	16-35	0-0
Chemicals and Dusting	22-35	12-24	0-7	0-0
Storage - Supplies	32-65	8-17	10-17	10-17
Combining-Mch. Hire	0-0	25-36	0-0	0-0
Equipment Repair Costs	35-50	16-25	12-14	12-14
Gas and Oil Costs	31-46	19-26	10-14	10-11
Irrigation & Pump Costs	30-60	30-60	23-50	12-22
Labor	50-75	12-25	14-20	12-16
Misc. Expense - Auto, Pickup, Utilities	22-32	16-19	8-10	8-10
Int. Operating Capital	24-32	10-14	6-8	4-7
Total Variable Costs	$ 466-790	$ 192-394	$ 99-200	$68-116
Fixed Costs				
Overhead Charge	$ 21-24	$ 19-22	$ 6-7	$ 6-7
Machinery and Equipment Fixed Costs (Deprec., Taxes & Ins.)	56-93	30-65	25-57	20-25
Interest on Machinery, Equip. and Overhead	27-35	24-27	16-25	16-25
Land Charge	50-175	50-175	30-125	30-80
Total Fixed Costs	$ 154-327	$ 123-289	$ 77-214	$72-137
TOTAL ALL COSTS	$ 620-1117	$ 315-593	$ 176-414	$140-253

*Costs Range selected by Duane Steinhart, Extension Agent Farm Management, from Bulletin 490A, "Costs for Selected Crops in a Closed Basin, San Luis Valley, Colorado." An estimated cost adjustment was made in 1979, 1980, 1981, and 1982.

1982 ACRE COSTS FOR SELECTED CROPS

Operating Costs	POTATOES	BARLEY	WHEAT	HAY
Fertilizer	$ 95	$ 33	$ 54	$ 8
Chemicals	29	10	9	0
Seed-Storage-Other Crop Costs	183	21	17	2
Utilities	9	3	1	3
Machine Repair	77	17	18	14
Machine Hire	12	29	37	9
Fuel-Oil	43	15	15	8
Irrigation	54	47	39	10
Auto	2	1	1	1
Interest	118	37	42	63
Labor	74	14	14	5
Building Repair	3	3	1	1
Insurance	12	5	7	1
Taxes	18	9	12	8
Miscellaneous	7	4	4	2
Cash Rent-L.L. Costs	50	23	40	0
Total Cash	$ 786	$ 271	$ 311	$ 135
Plus: Estimated Costs For:				
Machinery Depreciation	$ 70	$ 11	$ 11	$ 11
Building Depreciation	25	4	4	4
Total Cash	$ 881	$ 286	$ 326	$ 150

APPENDIX F

SUMMARY OF COMPUTER SIMULATION RESULTS FOR STUDY CASE 1

TABLE F-1

ALLOCATION OF INCREASED STREAMFLOW ON THE RIO GRANDE RIVER

CURRENT INSTITUTIONAL FRAMEWORK

LEVEL OF TREATMENT - 10%

	Colorado						N.M.	Texas		
Year	Region 1	Region 2	Region 3	Region 4	Region 5	R. G. Res.	MRGCD	R. G. Proj.	Returns	Total
1968	3,750	1,698	0	2,511	430	0	2,097	5,260	348	15,746
1969*	2,803*	1,971*	742	2,702*	362	0	556	7,245	428*	16,381*
1970	5,458	293	0	2,453	444	0	2,289	5,400	356	16,337
1971	2,630	1,163	943	4,422	671	0	1,960	2,775	681	14,564
1972*	3,599	2,753	0	2,326*	892	0	1,829	2,528	321*	13,927*
1973	2,040	781	83	1,308	738	139	0	11,119	185	16,208
1974*	3,711*	975	321	3,323	711	0	1,248	1,747	483*	12,036*
1975	1,591	1,125	122	1,534	211	167	861	11,007	218	16,618
1976*	4,230*	1,538	667	1,345	588	0	2,097	3,331	231*	13,796*
1977	4,948	1,404	556	3,477	1,516	0	1,242	0	523	13,143
1978	5,165	1,075	44	2,585	602	0	1,582	2,789	361	13,842
1979	0	0	0	0	13	27	0	16,531	0	16,571
1980	2,972	559	869	1,136	223	278	140	8,437	214	14,614
1981*	2,393*	3,074	59	4,181	850	0	1,857	2,570	584*	14,984*
1982	4,333	164	217	2,770	196	0	679	7,940	404	16,299
	Mean Annual Allocations					7,863	1,229	5,912	356	15,004

*Revised 10/16/84

ALL QUANTITIES ARE IN ACRE FEET

TABLE F-2

ALLOCATION OF INCREASED STREAMFLOW ON THE RIO GRANDE RIVER

CURRENT INSTITUTIONAL FRAMEWORK

LEVEL OF TREATMENT - 50%

	Colorado						N.M.	Texas		
Year	Region 1	Region 2	Region 3	Region 4	Region 5	R. G. Res.	MRGCD	R. G. Proj.	Returns	Total
1968	16,096	7,502	1,653	12,150	2,218	556	10,524	28,466	1,964	79,165
1969	21,698	9,986	1,506	4,952	1,955	0	9,449	31,260	799	80,806
1970	22,228	3,909	358	13,269	2,334	0	11,620	28,312	1,913	82,030
1971	14,584	7,501	3,856	17,466	3,349	0	10,382	14,879	2,741	72,017
1972	19,631	8,762	36	14,096	4,221	0	9,897	13,617	2,134	70,260
1973	5,469	2,215	83	4,728	861	708	0	66,762	680	80,826
1974	17,424	4,917	1,868	17,037	3,399	0	6,524	9,050	2,521	60,219
1975	7,065	2,281	1,502	6,307	1,195	833	2,486	61,487	998	83,156
1976	19,139	8,974	1,964	6,346	2,695	0	10,824	18,129	1,069	68,071
1977	12,439	7,232	3,918	28,679	6,023	0	4,026	5,302	4,283	67,619
1978	23,933	5,391	1,478	14,202	2,667	0	8,067	14,282	2,089	70,020
1979	0	0	0	0	0	0	3	83,265	0	83,268
1980	11,587	2,769	3,850	7,700	1,098	1,443	458	44,569	1,352	73,474
1981	18,628	5,848	6,424	14,388	4,444	1,444	10,314	13,088	2,456	74,578
1982	17,017	4,409	2,422	11,937	777	0	2,082	42,582	1,942	81,226
	Mean Annual Allocations					37,002	6,444	31,670	1,796	75,116

ALL QUANTITIES ARE IN ACRE FEET

TABLE F-3

ALLOCATION OF INCREASED STREAMFLOW ON THE RIO GRANDE RIVER

CURRENT INSTITUTIONAL FRAMEWORK

LEVEL OF TREATMENT - 100%

	Colorado						N.M.	Texas		
Year	Region 1	Region 2	Region 3	Region 4	Region 5	R. G. Res.	MRGCD	R. G. Proj.	Returns	Total
1968	30,526	11,484	4,446	19,804	4,483	2,387	19,903	63,752	3,078	156,785
1969	41,228	16,764	2,144	11,229	3,316	0	3,789	82,822	1,715	161,292
1970	39,474	11,487	621	21,183	4,692	474	23,399	61,906	3,005	163,236
1971	31,106	15,885	4,652	32,660	6,813	0	21,135	31,302	4,889	143,553
1972	44,747	13,019	469	23,888	8,344	0	20,401	28,704	3,370	139,572
1973	7,330	2,949	183	5,894	1,608	1,430	0	141,439	726	160,833
1974	37,019	12,714	2,603	27,355	6,139	0	14,091	19,486	4,006	119,407
1975	9,441	5,290	2,588	6,711	2,384	1,861	4,249	132,803	1,059	165,327
1976	39,008	14,591	3,354	12,434	5,356	0	22,098	39,140	1,987	135,981
1977	27,351	17,021	9,702	44,897	10,591	0	10,324	13,701	6,956	133,587
1978	40,509	13,202	1,550	31,776	5,287	0	16,463	30,203	4,551	138,990
1979	0	0	0	0	0	0	2	166,530	0	166,532
1980	16,868	4,492	5,309	12,616	2,111	2,887	1,351	100,406	2,131	146,040
1981	34,586	9,574	10,298	22,324	8,830	5,219	29,694	27,554	3,837	148,079
1982	31,413	10,479	4,206	16,538	1,553	0	2,815	94,109	2,603	161,113
	Mean Annual Allocations					67,784	12,648	68,924	2,928	149,355

ALL QUANTITIES ARE IN ACRE FEET

TABLE F-4

ALLOCATION OF INCREASED STREAMFLOW ON THE RIO GRANDE RIVER

CURRENT INSTITUTIONAL FRAMEWORK WITH INCLUSION OF CLOSED BASIN PROJECT

LEVEL OF TREATMENT - 10% (1ST STAGE OF CLOSED BASIN)

	Colorado						N.M.	Texas		
Year	Region 1	Region 2	Region 3	Region 4	Region 5	R. G. Res.	MRGCD	R. G. Proj.	Returns	Total
1968	6,257	2,647	36	4,570	1,890	0	181	454	637	16,035
1969	5,589	3,938	1,343	3,217	1,960	0	32	416	542	16,495
1970	9,042	1,032	0	3,933	1,974	0	163	384	547	16,528
1971	3,311	1,948	988	5,979	1,725	0	345	488	901	14,784
1972	4,594	3,917	0	3,426	1,669	0	200	276	476	14,082
1973	6,243	1,892	556	5,243	1,988	139	0	731	769	16,792
1974	4,970	975	602	3,657	1,390	0	212	296	549	12,102
1975	6,083	1,460	1,103	5,662	2,001	167	57	731	864	17,264
1976	6,199	2,575	1,079	2,117	1,670	0	113	180	368	13,933
1977	5,391	1,588	556	3,607	1,516	0	503	0	541	13,161
1978	7,387	1,075	412	2,965	1,670	0	149	263	440	13,921
1979	4,896	130	2,456	3,721	2,056	847	0	3,151	686	17,257
1980	5,886	1,163	2,379	3,105	1,753	278	7	423	594	14,994
1981	3,726	3,676	205	5,053	1,753	0	295	408	716	15,116
1982	6,863	164	1,037	5,917	1,980	0	65	760	897	16,792
	Mean Annual Allocations					14,532	155	597		15,284

ALL QUANTITIES ARE IN ACRE FEET

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